

Mines and Minerals Branch Report of Activities 1987, Part A

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and D.R. MacDonald,
Editors

Report 87-5

Nova Scotia



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FOREWORD

On behalf of all the staff of the Nova Scotia Department of Mines and Energy, I welcome you to the 1987 Open House and Review of Activities. This has been a remarkable year indeed; it being one of the most active on record. Exploration expenditures, areas under license and lease, employment and value of production all show substantial increases over previous years.

Thanks to the Canada - Nova Scotia Mineral Development Agreement, we have also been able to carry out, in co-operation with the federal department of Energy, Mines and Resources Canada, a record number of programs to evaluate and to promote the development of our mineral resources.

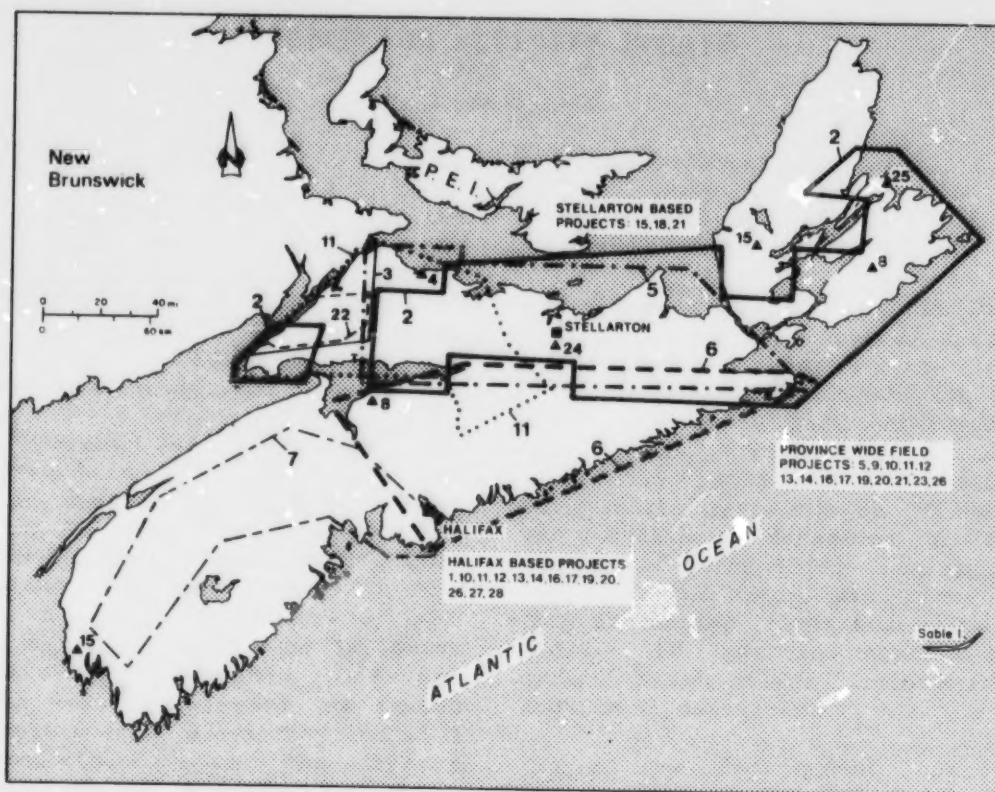
This year, 1987, marks the first full year of production at the tin mine in Yarmouth County. New petroleum and gas discoveries in the Sable Island area were also announced during the year. In addition, 1987 marks the 100th anniversary of the Mining Society of Nova Scotia and the 125th anniversary of the Nova Scotia Department of Mines and Energy.

This publication provides the reader with a preliminary summary of the sixty or more projects being carried out in the Province by this Department and the federal Department of Energy, Mines and Resources in Ottawa. The projects represent an expenditure of about \$5.0 million, which is also a record for such programs in this Province. I am also pleased to report that a number of our universities are actively involved in these programs, all of which are designed to evaluate the geology and mineral resource potential of Nova Scotia.

The record levels of exploration expenditures and the substantial investment by both the federal and provincial governments under the Canada - Nova Scotia Mineral Development Agreement have resulted in record levels of employment within the mineral industry of the Province. I am confident that we will see a number of new mines in the very near future. This will ensure the continuous growth of this important industry in the years ahead.



Joel R. Matheson, Q.C.
Minister of Mines and Energy



NOVA SCOTIA DEPARTMENT OF MINES AND ENERGY PROJECTS - 1987

MINERAL RESOURCES DIVISION

1. Catchment Basin Geochemical Study of the Cobequid Highlands
2. Regional Reconnaissance Geochemical Project
3. Cumberland Basin Project
4. Pugwash Salt Project
5. Quaternary Mapping and Till Geochemistry Project
6. Meguma Gold Project
7. South Mountain Batholith Project
8. Base Metals Deposit Study
9. Metallogenic and Tectonic Studies
10. Public Awareness and Education

MINERAL DEVELOPMENT DIVISION

11. Aggregates Project
12. Building Stone Project
13. Gypsum and Anhydrite Project
14. Diatomaceous Earth Project
15. Various Commodities Project
16. Fillers and Extenders Field Investigations Project
17. Gold Resource Project

18. Core Library Project
19. Bibliographic Database Activities, Mineral Occurrences Databases Activities, Drillhole Database Activities, Gold Bibliography
20. Mineral Land Use Policy Development Project
21. Exploration Monitoring/Regional Office

ENERGY RESOURCES DIVISION

22. Cumberland Basin Seismic Program, Coal Depositional/Sedimentological Study
23. Oil Shale Project
24. Coal and Oil Shale Exploration
25. Sedimentology of the Hub Seam-Prince Mine
26. Petroleum Exploration Monitoring
27. Offshore Petroleum/Natural Gas Evaluation
28. Onshore Petroleum/Natural Gas Evaluation



PETROLEUM ACTIVITY UPDATE¹

D. J. MacDonald

INTRODUCTION

Since the early autumn of 1985 the petroleum industry has continued its exploration activity with cautious optimism. Offshore drilling continued with 1 successful gas delineation at Thebaud, 1 new oil find with subsequent delineation at Panuke, and 2 dry holes.

In November 1986, the Canada-Nova Scotia Offshore Oil and Gas Board issued an exploration agreement on a parcel of offshore lands that were nominated by industry in the 1986 Call for Proposals.

In May 1987, an act to implement the Canada-Nova Scotia Offshore Petroleum Resources Accord was passed by the Nova Scotia Legislature and will be proclaimed once the mirror legislation is passed in Parliament.

A highlight of onshore activity was a geophysical program conducted by Canjay Exploration of Calgary on licenses held by Consultants A.G.R.E.N. Canada Incorporated.

ADMINISTRATIVE AND LEGAL FRAMEWORK

For administrative purposes, oil and gas activity in Nova Scotia is divided into offshore or onshore regions. The offshore region is administered by the governments of Nova Scotia and Canada under the provisions of the Canada-Nova Scotia Offshore Petroleum Resources Accord, while the onshore region is administered solely

by the provincial government.

CANADA-NOVA SCOTIA OFFSHORE PETROLEUM RESOURCES ACCORD

The Canada-Nova Scotia Offshore Petroleum Resources Accord, a federal-provincial agreement on resource management and revenue sharing in the offshore, was signed on August 26, 1986. It replaces and contains significant improvements to the Canada-Nova Scotia Agreement on Offshore Oil and Gas Resource Management and Revenue Sharing of March 1982. Legislation to implement the accord was introduced to the provincial Legislature in March 1987. The important aspects of the accord, which follow, involve resource and fiscal management.

A new independent board will replace the existing Canada-Nova Scotia Offshore Oil and Gas Board. The board will be comprised of 5 members including the Chairman, who will be appointed jointly by the two governments. The other 4 members will be appointed jointly, or alternatively, with each government appointing 2 members. The board and its staff will deal with day-to-day matters directly related to the management of offshore petroleum resources, which are currently handled by the Canada Oil and Gas Lands Administration (COGLA). Certain board decisions are considered fundamental and will be subject to the approval by the two governments. The types of decisions include:

Calls for Bids and the issuance of

¹ Funded by Nova Scotia Department of Mines and Energy, and Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

exploration licenses following a Call for Bids,

setting terms and conditions of significant discovery licenses and production licenses, and

final approval of development plans.

Fundamental decisions related to the Sable Island "footprint" and the Bay of Fundy are approved by the Minister of the Nova Scotia Department of Mines and Energy (NSDME). Development plan approval regarding the remainder of the Nova Scotia offshore is by the Minister of NSDME alone, but all other fundamental decisions are approved jointly by the Ministers of the federal and Nova Scotia governments.

In turn, the federal energy minister may act unilaterally to override board decisions or the provincial minister's veto, if in the opinion of the federal minister, the decision or veto unreasonably delays the achievement of security of crude oil supply as defined in the accord. In the case of disagreement between ministers on the question of delay of security of supply, the matter will be decided by the National Energy Board.

The accord gives Nova Scotia control over offshore royalties. Subsequent to the accord signing, the principles of the new offshore royalty regime for the Province were announced in 1987. This system consists of a base royalty equal to 2% of gross revenues until project payout, and a royalty equal to 30% of net profits before tax after project payout. This royalty takes into account the unique characteristics of offshore development, which require a long lead time for exploration, delineation and construction, during which no revenue is generated. Overall, the royalty regime encourages development, while providing a fair share of offshore

production revenues to the people of Nova Scotia.

OFFSHORE EXPLORATION AND DEVELOPMENT

The decline in world oil prices which has caused a worldwide decrease in exploration has also affected Nova Scotia offshore activity. Drilling commenced on 6 wells in 1986 on the Scotian Shelf, compared with a peak of 14 wells in 1984 and an average of 8 wells per year since 1981. In addition, 3 wells were spudded in the first 5 months of 1987.

To provide further detail on the Cohasset oil discovery, 613 km of 3-D seismic data were acquired in the past year, with an additional 78 km of well-site seabed survey completed.

The following operators participated in offshore activities in the past year:

- Shell Canada completed its recent East Coast drilling program with the delineation gas well Glenelg N-49 and the exploration well Panuke B-90 which encountered oil.
- Mobil and its partners completed the Thebaud C-74 delineation gas well and plan to continue their offshore drilling program by commencing a number of wells in 1988.
- Husky/Bow Valley concluded its recent Scotian Shelf exploration program, with the Chebucto K-20 well, which tested only a minor quantity of gas, just south of the North Triumph discovery.
- Petro-Canada and its partners drilled a wildcat well on the Como structure, just west of the Cohasset oilfield and northwest of the Panuke B-90 oil discovery, however no tests were conducted. A delineation well on the Panuke

structure was spudded during July. Drill stem tests were concluded on this well and an extended production test, which recovered 3821 m³ of light, sweet crude for refinery processing, was also completed.

Canterra drilled the Whycomomagh N-90 wildcat well with the semi-submersible Sedco 710. The hole was abandoned without testing.

DEVELOPMENT PROSPECTS

VENTURE GAS PROJECT

Mobil and its partners completed the third delineation well (Thebaud C-74) on the Thebaud Structure. The results were encouraging particularly in deeper, previously untested horizons, and additional estimated reserves were attributed to the Thebaud field.

Mobil continued engineering analysis of various development scenarios in an effort to optimize the project, and initiated discussions with Shell and its partners to examine the feasibility of developing jointly the natural gas discoveries by Shell in the vicinity of Sable Island in conjunction with the Venture, South Venture and West Venture fields. This joint development could further optimize the development of gas off shore Nova Scotia and lead to earlier production. The governments of Nova Scotia and Canada are also investigating ways to assist the project partners to initiate the project at an early date.

SMALL OILFIELD DEVELOPMENT

A good level of progress has been made by Petro-Canada and its partners to evaluate the viability of small-scale oilfield development. The group has undertaken extensive reservoir and facility analysis on Cohasset, a small field discovered in 1973 and successfully delineated in 1986.

Analysis to date indicates that a viable commercial development is possible, utilizing a converted jack-up drilling rig as a production platform and transporting the oil to shore using shuttle tankers.

The oil discovery by Petro-Canada and its partners at Panuke B-90, 10 km southwest of Cohasset, opens the possibility of another small oilfield that may be developed in conjunction with Cohasset. This field was successfully delineated by the Panuke F-99 well, which was completed in August 1987.

ONSHORE ACTIVITY

Four onshore exploration agreements, two of which are with Chevron, were renegotiated under the Petroleum Resources Act in 1986 and continued into 1987. In addition, a new exploration agreement was issued to Consultants A.G.R.E.N. Canada Incorporated and was considered effective July 2, 1986.

The exploration agreements of Chevron cover 2 areas. The Cumberland Basin block extends over 1 044 600 ha while the Cape Breton block has an area of 588 483 ha. As of May 1, 1986, Chevron has a 3-year term to drill one well on each block to be able to hold the land. Aggregate exploration expenditures by the end of the third year must total \$4.00 per ha (\$1.62 per acre).

During this past field season, Chevron conducted field mapping and sampling and examined cores at the Stellarton office of NSDME.

In autumn 1986, Canjay Exploration Limited of Calgary conducted a geophysical program in the Kennetcook area in accordance with the exploration agreement held by Consultants A.G.R.E.N. Canada Incorporated. The survey covered 2.67 km and was completed in about 2 weeks. Evaluation

of the data will determine if there is a closed structure worthy of exploration drilling. The exploration agreement is for a 3-year period commencing July 2, 1986, and includes a drilling commitment prior to the third year.

Miles also have approximately 127 670 ha under an exploration agreement. The 3-year term commenced May 1, 1986, with the requirement that a petroleum well be spudded prior to the end of the third year. A preliminary geological evaluation of the acreage has been completed.

The fourth of the original exploration agreements was issued to Sigma Resources Incorporated in 1986. However, financial constraints caused the company to surrender its land in July 1987.

The Nova Scotia Department of Mines and Energy, through funding by the Canada-Nova Scotia Mineral Development Agreement, is presently undertaking a study of the petroleum source rock potential for onshore Nova Scotia. This study, scheduled for completion in the spring of 1989, is intended to aid companies in identifying regions in Nova Scotia which are most prospective for petroleum exploration. The study centres on data obtained from organic

geochemical analysis. A field sampling program will augment compiled data from previously reported oil shows. Samples are from surface outcrop and available drill core and cuttings.

The immediate goal is to delineate, from a petroleum perspective, the quantity, quality and thermal maturity of organic-rich strata. Work will concentrate on the Carboniferous aged Sydney, Mabou-Lake Ainslie, Bras d'Or Lakes, Antigonish, Stellarton, Musquodoboit-Shubenacadie-Kennetcook and Cumberland sub-basins. Additional, less detailed work will be conducted on the St. Marys graben of southeast Cape Breton, and on smaller areas of Carboniferous strata within Nova Scotia.

The compiled information will lead to a better understanding of the oil or gas potential of the rocks. The data and interpretations will be published in map and report form.

The Petroleum Resources Section has produced two publications titled *Petroleum Wells and Drillholes with Petroleum Significance and Surface Petroleum Shows*. The first is a compilation of available information on onshore wells with petroleum significance. The second publication is a compilation of all available reports on significant onshore surface petroleum shows.

PRELIMINARY INTERPRETATION OF SEISMIC STRATIGRAPHY OF LATE CARBONIFEROUS STRATA IN THE ATHOL SYNCLINE, CUMBERLAND BASIN: IMPLICATIONS FOR COAL EXPLORATION¹

J. H. Calder

INTRODUCTION

During 1985-1987, 80-line km of seismic data were shot as a federally funded program under the Canada - Nova Scotia Mineral Development Agreement. The results of initial processing reveal the detailed stratigraphic nature of the Cumberland Group and, to a lesser degree, the Riversdale Group throughout most of the Athol Syncline. The coal-bearing lithofacies assemblages appear to provide well defined reflectors in the survey sections. Where possible, the seismic lines were run to tie in the known surface geology of the Springhill and Joggins-Chignecto coalfields (Fig. 1). The location of the lines and the year(s) the line was shot are summarized in Table 1.

PRELIMINARY INTERPRETATION OF STRATIGRAPHY AND STRUCTURE

The objective of the Cumberland Basin seismic program was to define the stratigraphic and gross structural relationship between known coalfields (Springhill, Joggins-Chignecto) and coal occurrences (e.g. Newville Lake) so as to shed light on possible coal exploration targets within the Athol syncline. The coal-bearing strata of the Joggins-Chignecto and Springhill coalfields occur within a package of well defined reflecting events that can be traced virtually throughout the Athol syncline. The interpretation of

the seismic data, in progress by the authors, will provide valuable insight into the precise stratigraphic relationship between the two major coalfields of Joggins-Chignecto and Springhill. This relationship is obscured in line 1004/5/6 between Fenwick (Joggins-Chignecto) and Springhill (Fig. 1) due to the presence of faults near Fenwick and the northern part of the Springhill coalfield. Re-processing of the data may enhance the nature of these structural features.

The well defined reflecting package can be widely traced throughout the syncline and to the coal-bearing strata within the two coalfields. This does not necessarily mean that these events represent individual coal seams of basin-wide extent. Rather, the coal-bearing strata typically comprise thick multi-storied sandstones, and mudrocks would provide the required velocity contrasts for such reflectors.

The structural configuration of the Cumberland Group within the Athol Syncline is well defined in seismic sections from lines 1001, 1002 and 1004/5/6 (Fig. 1). The Cumberland Group is folded into a broad syncline that is asymmetrically steepened on the north limb adjacent the Minudie Anticline. The axis of the Syncline trends virtually east-west.

¹ Funded by the Geological Survey of Canada under the Canada - Nova Scotia Mineral Development Agreement

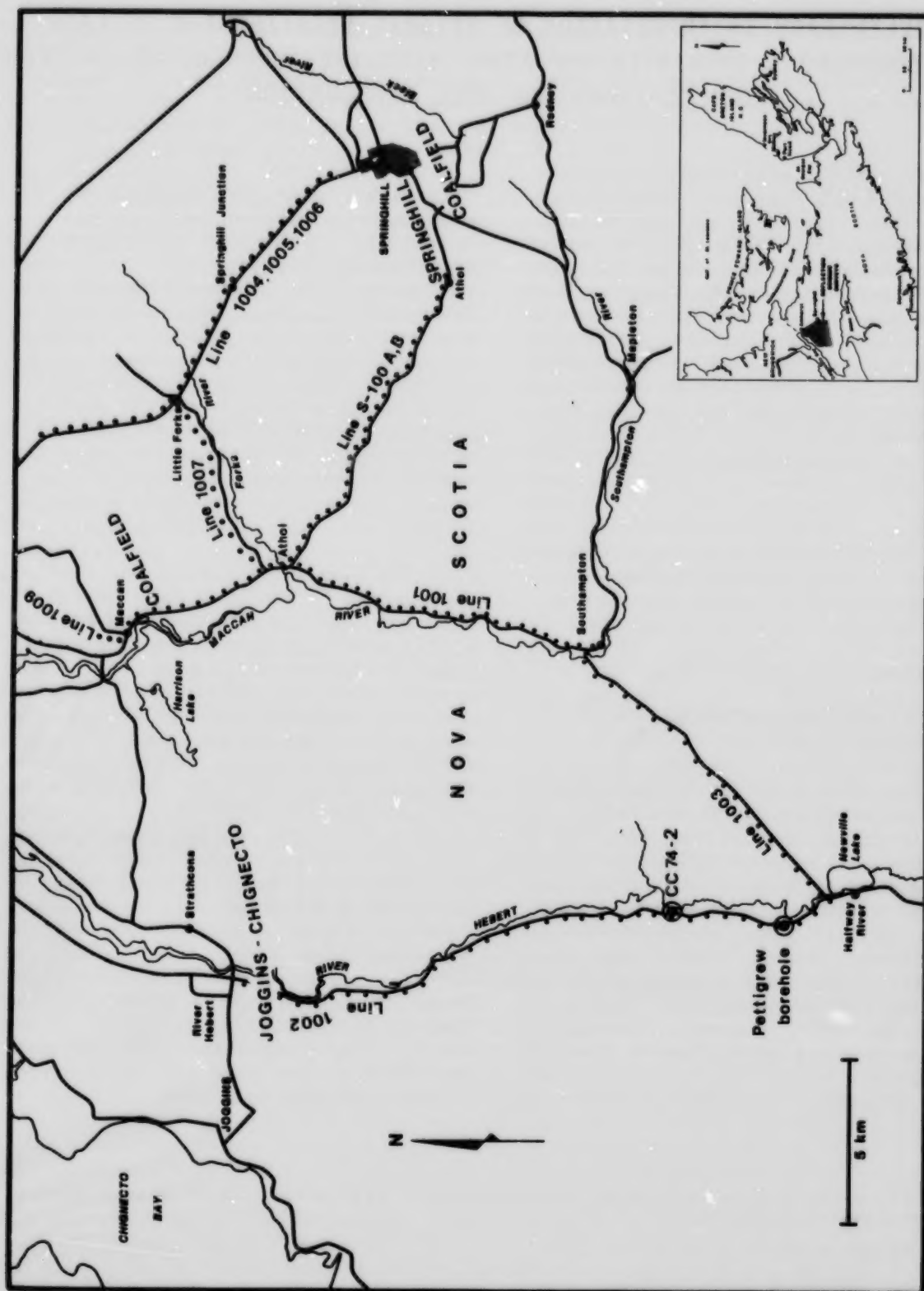


Figure 1. Location map showing coalfields and seismic lines

Table 1. Summary information pertaining to lines shot during Cumberland Basin seismic reflection study

LINE	YEAR SHOT	LOCATION	TIE-IN WITH KNOWN COAL-BEARING DISTRICTS
Line 100, A and B	1985, 1987	Springhill - Athol (Athol Road)	Springhill coalfield
Line 1001 Line 1009	1986 1987	Marcan-Southampton (Route 302)	Joggins-Chignecto coalfield
Line 1002	1986	Halfway River - River Hebert (Boar Back Road)	(Newville Lake) Joggins-Chignecto coalfield
Line 1003	1986	Halfway River - Southampton (Route 2)	(Newville Lake)
Line 1004 Line 1005 Line 1006	1986 1987 1987	Fenwick-Springhill (Route 2)	Joggins-Chignecto and Springhill coalfields
Line 1007	1987	Little Forks Athol (Little Forks Road)	-
Line 1008	1987	Chignecto Game Sanctuary	-

IMPLICATIONS FOR COAL EXPLORATION IN THE ATHOL SYNCLINE

A portion of the survey, of particular interest for coal-exploration, is the central section of line 1001 between Athol and Southampton, approximately 18 km west of the Springhill coalfield (Fig. 2). Within the major reflecting package, that occurs over an interval of approximately 2.6 msec, individual reflectors record progressive onlap of younger strata to the south. This aspect of the stratigraphy closely resembles the progressive onlap of the coal seams of the Springhill coalfield over distal alluvial fan-related deposits to the south (for comparison see Boehner *et al.*, 1986, Fig. 26). The resemblance in stratigraphic architecture between the two areas implies similar basin infilling and paleogeography which can be considered

favourable for coal potential.

Should coal seam development here mirror that of the Springhill coalfield (Calder, 1984; 1986), then the most extensively developed coals would be expected to occur at approximately 1400 m depth, near the axis of the Athol Syncline. Younger, less extensively developed coals situated further south toward Southampton would be expected to occur at approximately 1100 m depth. These depths are calculated from inferred velocities; accurate velocity data await future deep drilling and subsequent sonic logging.

To the west along the Boars Back Road line (1002) between Newville Lake and River Hebert (Fig. 1), coal exploration prospects are suggested by the occurrence of coal seams in the Pettigrew borehole drilled 1.5 km north of Newville Lake in 1903, and the Cera-Caledonia hole CC75-3 drilled a further

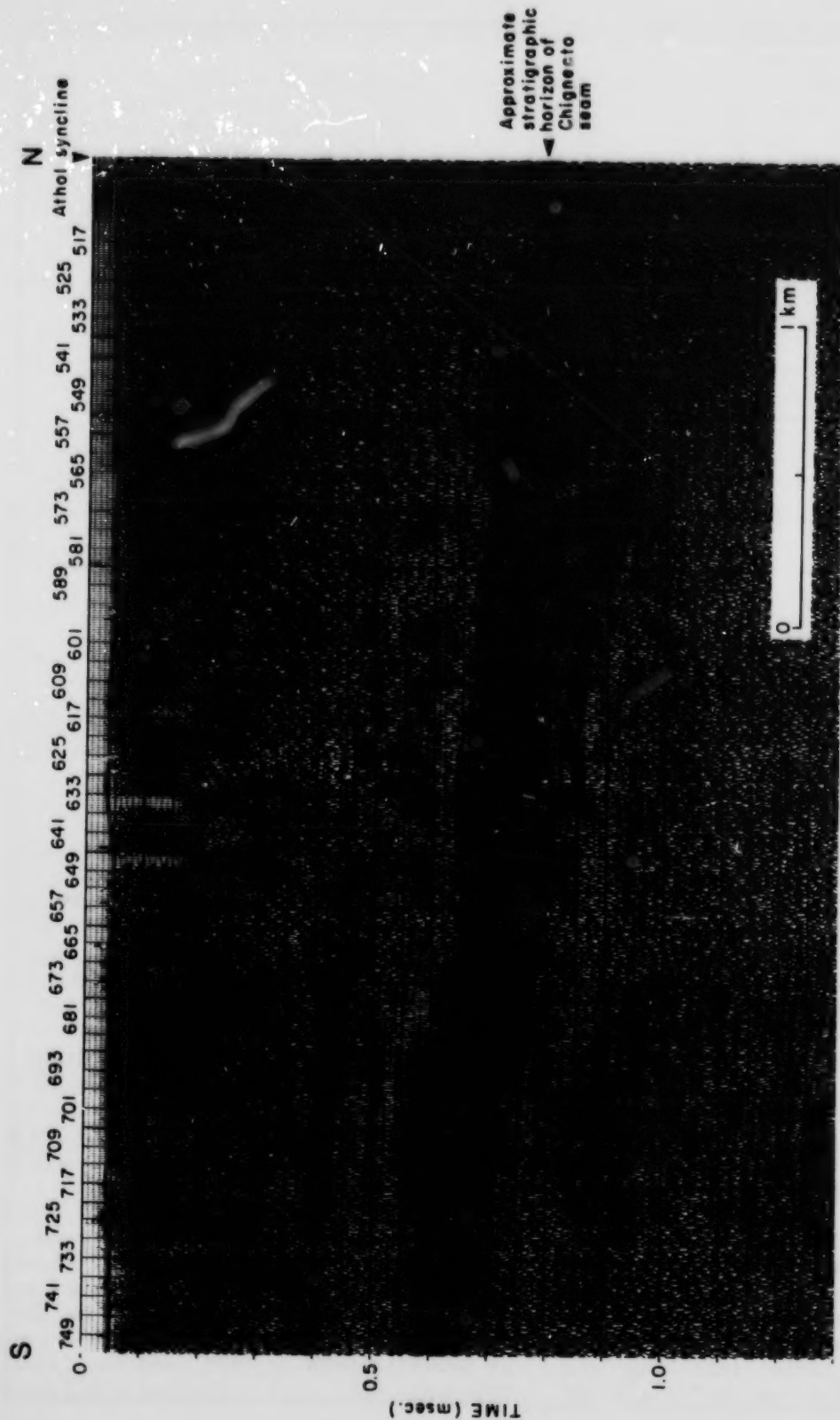


Figure 2. Portion of seismic line 1001, between Athol and Southampton. Well defined reflectors (0.55 to 1.40 msec) are interpreted as thick mudrock/sandstone lithofacies within the Cumberland Group which are potentially coal-bearing. Note progressive onlap to south.

3 km north in 1974 (Fig. 1). Preliminary interpretations suggest that these coal-bearing strata are structurally dislocated from the deeper, well defined reflector package to the north by a major basin-related fault system. This package is in part stratigraphically equivalent to the Joggins coal section. Exploration efforts in this vicinity await tectonic interpretation of these major structural features.

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HISTORY OF MIGRATION OF A CHANNEL BELT IN THE OFFSHORE PRINCE RESOURCE BLOCK MORIEN GROUP, NOVA SCOTIA

J. H. Calder, K. S. Gillis, D. J. MacNeil and R. D. Naylor

The prediction of the occurrence and behavior of channel sandstones in the immediate roof strata of productive seams is one of the major problems of underground coal mining geology in the Sydney coalfield (Forgeron *et al.*, 1986). This is a critical factor in mine planning since these sandstone bodies and associated features can impact on mineability, coal quality and safety at the face. The problem is compounded in the submarine Sydney coalfield because of the lack of data in advance of mine workings (e.g. only 5 offshore drillholes in the 35 km² Prince resource block).

Geologists of the Coal Section of Nova Scotia Department of Mines and Energy (NSDME) in co-operation with the Geology Department of the Cape Breton Development Corporation (CBDC), examined a case in the Prince resource block (Fig. 1) in which a channel sandstone overlying the Hub seam was penetrated by a drillhole (P-6). A study of the sedimentology of the Hub seam roof strata from 4 drillholes within the resource block was integrated with data from underground mapping by the Geology Department of the CBDC, to develop a predictive model of the regional stratigraphy and facies relationships of the immediate Hub roof interval (Fig. 2).

The approach to the problem involved:

1. detailed logging of the available cored intervals from the offshore drillholes (10 cm diameter cores) using a process-oriented lithofacies scheme for rock descriptions (Table 1),
2. description of lithofacies types,
3. grouping of lithofacies into 3

associations and subsequent interpretation of depositional environments (Table 2),

4. interpretation of the depositional history of each cored interval and correlation of cores, and
5. integration of interpreted core data with underground mapping to develop a preliminary model of the genesis of the paleo-river system.

The stratigraphic model is illustrated by a schematic cross-section (Fig. 2) which was constructed by normally projecting the holes onto a roughly north-south section (see Section A-B on Fig. 1). Underground mapping done by the CBDC has provided some spatial constraints on the schematic aspects of this model, particularly with regard to the lateral extent of the channel sandstone body in the roof of the Hub seam.

The boundaries of the various lithofacies associations, and the upper and lower boundary of the Hub seam interval are shown in Figure 2. The section (~5m thick) of the thinly interbedded association (No. 2) in drillhole H-12A is thought to represent medial floodplain overbank deposits. The thickness and consistently cyclic nature of the lithofacies comprising the association suggests entrenchment of a local major channel system. This association probably comprises overbank deposits from the channel system represented by the sandstone lithofacies association (No. 3) in drillhole H-12B.

Certain aspects pertaining to the nature of the channel system can be deduced from the study. The river that deposited the channel complex appears to have become at least partly

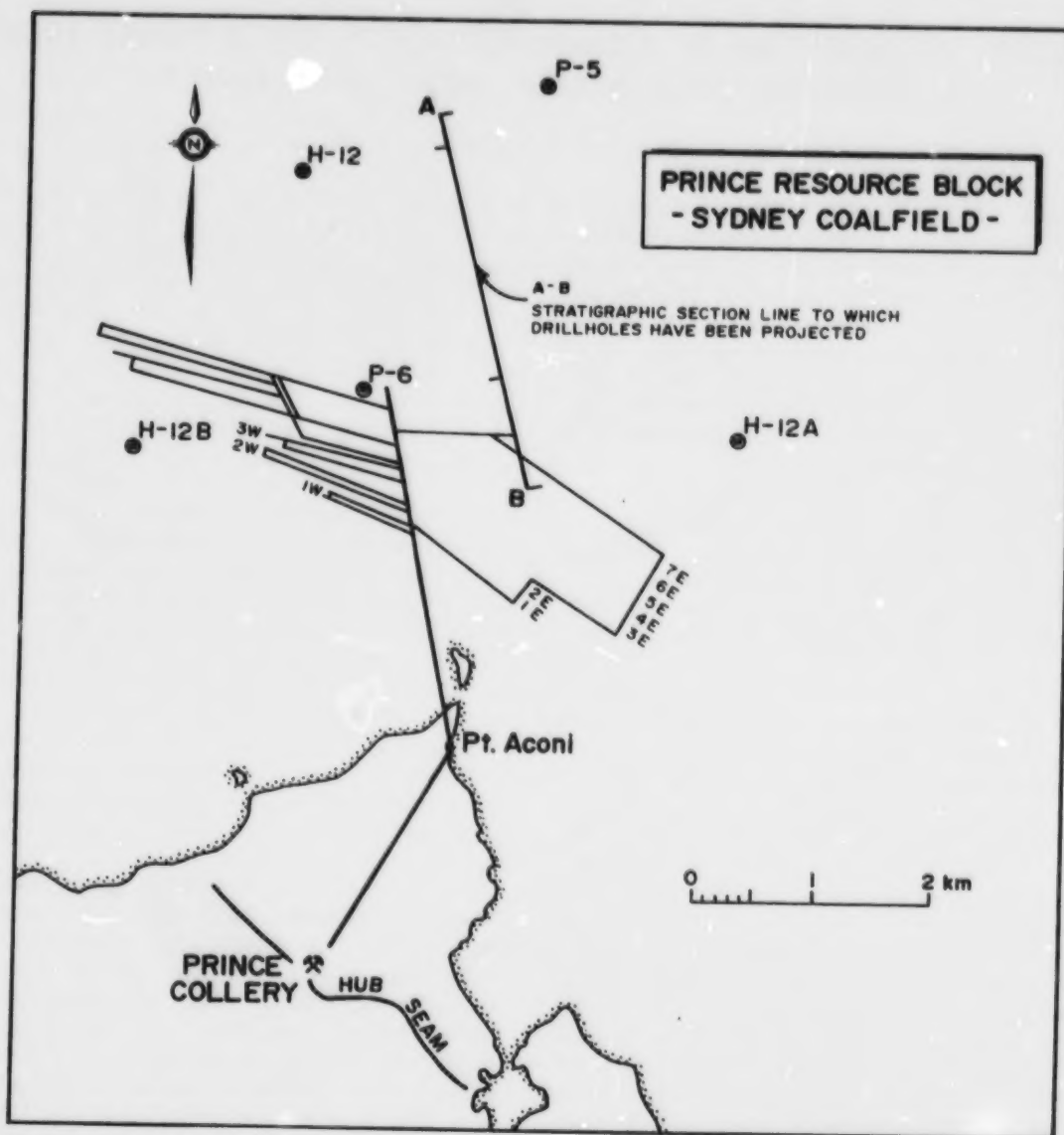


Figure 1. Plan view of the Prince resource block of the Sydney coalfield

entrenched in a site near H-12B. Vertical aggradation of the river is reflected by the consistent nature of the sandstone lithofacies association in H-12B and the laterally equivalent thinly interbedded association in H12A. An interpreted abandoned mudstone filled channel in H-12B suggests that the rivers may have episodically changed or abandoned courses through

avulsion.

Based on the nature and distribution of the channel-related lithofacies associations, the channel belt may have migrated or meandered northerly through time during the deposition of the amalgamated sandstone association in drillhole H-12B and P-6 (note inferred upward-stepping of

Table 1. Observed lithofacies in Hum seam roof cores - Prince resources block

LITHO-FACIES CODE	LITHOLOGY	COLOUR	GRAIN SIZE	PHYSICAL PROPERTIES SEDIMENTARY STRUCTURE	DEPOSITIONAL PROCESS	FOSSILS
Fm	silt-stone/ clay-stone	green-grey	silt to clay	- massive to normal graded silty layers or pale grey micro-laminae alternating with mottled clay laminae - siderite bands in lower part of units; can form sharp base. - units 5-220 cm	rapid to episodic deposition under quiescent conditions	Stigmaria rootlets; fern pinnules rare
Fmc	mudstone	dark grey	silt to clay	- organic-rich, massive to vaguely stratified - rare coaly laminae - rare siderite bands - bases sharp to gradational - units 2-75 cm	mud and plants deposited under quiescent reducing conditions	<u>Cordaites sp.</u> <u>Sigillaria sp.</u> <u>Calamites sp.</u> Stigmaria ficoides
Fc	carbonaceous mudstone	dark grey to black	silt to clay	- massive to banded fissile - rare internal slickensiding - bases gradational to abrupt - units 2-15 cm	mud and plants deposited under quiescent reducing conditions	Fern pinnules, <u>Annularia sp.</u> common; <u>Cordaites principalis</u> (leaves) <u>Calamites</u> fragments
Fd	siltstone	grey	silt to clay	- disrupted laminae, micro-faulting - siderite bands - clay-rich bases - derived from Fi	bedding deformed by various causes	plant impressions
C	coal	black	NA	- normal to micro-banded - gradational base	peat accumulation	pyritized Stigmaria
CF	shaly coal/ coaly shale	black	NA	- fissile - fusainous; normal banding; sulphurous - interlaminated with Fc - bases gradational to sharp - units 2-18 cm	peat accumulation with contemporaneous deposition of mud from flood waters	<u>Calamites</u> <u>Cordaites</u>
Cs	sapropelic coal	black	NA	- dull - conchoidal fractures - single occurrence 2 cm	accumulation of finely detrital plant remains from suspension	

NA = not applicable

Table 1. continued

LITHO-FACIES CODE	LITHOLOGY	COLOUR	GRAIN SIZE	PHYSICAL PROPERTIES SEDIMENTARY STRUCTURE	DEPOSITIONAL PROCESS	FOSSILS
Sm	sandstone	pale grey	very coarse to fine sand	- massive to faintly stratified • rare channel lags • abrupt to sharp (erosive) bases • units 2.5-100 cm	rapid in-channel deposition	plant fragments stems, <u>Sigillaria sp.</u>
Sp	sandstone	pale grey	fine to coarse sand	• planar cross-strata • rare intraformational clasts • sharp set bases • units 5-35 cm	traction; dunes (St in core) or transverse bars	macerated carbonaceous matter
Sr	sandstone	pale grey to grey	fine sand to silt	• ripple cross-laminae sometimes linguoid rarely climbing • bases sharply gradational to sharp • units 2.5-23 cm	traction; shallow lower flow regime	rare macerated plant material
Sh	sandstone	grey	fine sand	• planar to horizontal bedding lamination • lamination sometimes accentuated by carbonaceous debris • bases questionable • units 10-50 cm	shallow, planar bed-flow deposition; upper or lower flow regime	comminuted plant remains
Si	sandstone/siltstone	grey	very fine to fine sand and silt	• large-scale ripples to planar cross-laminae • parallel to wavy bedding • bases gradational to sharp • units 2.5-11 cm	overbank or drape (episodic)	rarely rooted
Sd	sandstone	grey	fine sand	• laminated to climbing ripples • bioturbation or penecontemporaneous microfaulting • bases sharp to gradational • units 25-29 cm	bedding deformed by various causes; pre-lithification	rarely rooted
Fi	siltstone	dark grey	silt and very fine sand	• lenticular lamination on cm scale; cross-bedded sandy lenses • siderite nodules • bases sharp to gradational • units 5-45 cm	episodic deposition of overbank fines	occasional siderite lined burrows; plant fragment bark; <u>Cordaite sp.</u>

Table 2. Summary of lithofacies associations from Hub seam and roof identified in offshore drillholes

LITHOFACIES ASSOCIATION	LITHOFACIES	PALEOGEOGRAPHIC SETTING	GEOMORPHIC REGIONS
Coal/mudrock	C, CF, Fc, Fmc, Fm (rare Cs, Fi, Si)	distal floodplain	lake/submerged floodplain; backswamp/peat mire; abandoned channel
Thinly interbedded sandstone/mudrock	Fm, Fi, Si, Sr (rare Sm, Sd)	medial floodplain	"lake" proximal to river channel; crevasse splay; levee
Sandstone	Sm, Smc, Sh, Sp, (rare Sr, Si, Fi)	river system	channel; near channel bars

sandstone body in Fig. 2). Subsequent to avulsion from this site, the belt may have found a new course trending from P-5 to the east of H-12A, as a possible response to a compaction-related nesting of channel bodies. Allen (1978) discussed such tendencies for a river to avoid sites overlying buried sandstone bodies, which may incur a positive topographic relief.

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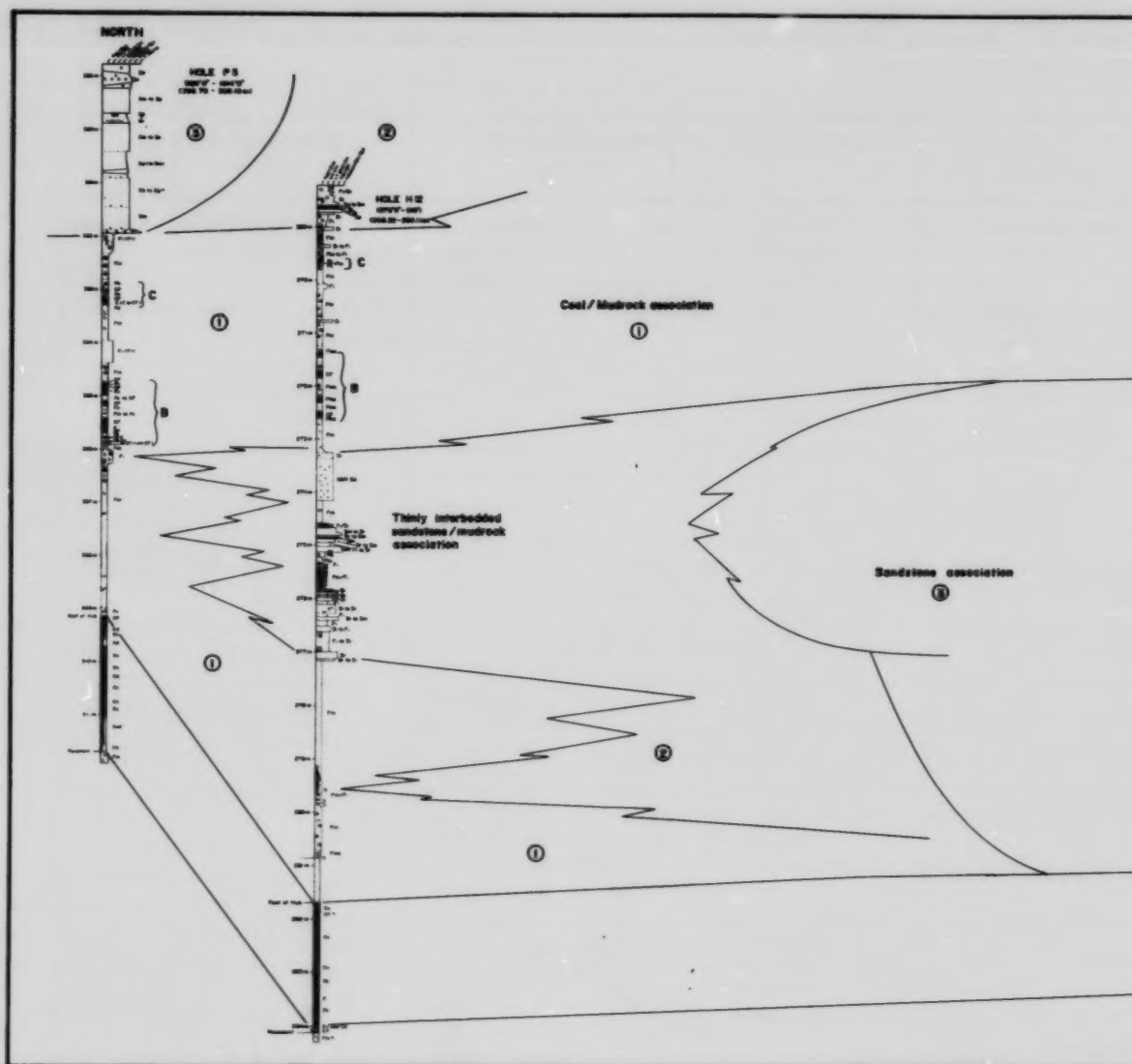


Figure 2. North-south section (A-B) of Hub seam and roof strata of the Prince mine resource block

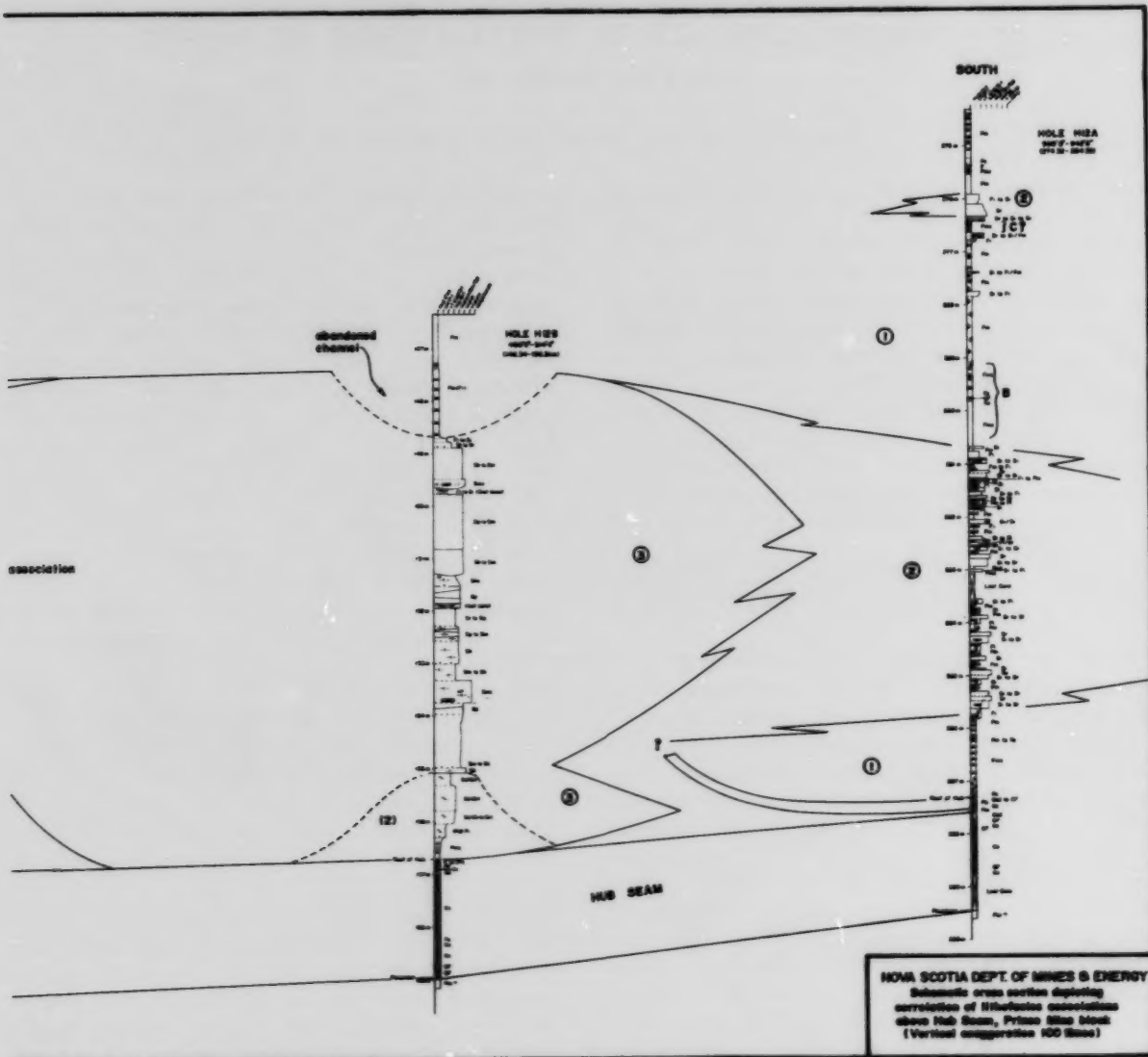


Figure 2. continued

REPORT ON INVESTIGATIONS OF OIL SHALE OCCURRENCES OF NOVA SCOTIA¹

R. D. Naylor, W. D. Smith and D. J. Conrod

The Nova Scotia oil shale project, which began in 1985 under the Canada-Nova Scotia Mineral Development Agreement (CNSMDA), has obtained geological and geochemical information on oil shale occurrences throughout the Province (Fig. 1). The aim of the project is to gather and provide information on the lithology, geochemistry, organic petrology and hydrocarbon yield of the oil shales to those interested in the resource. The nature of the oil shales of the Stellarton Basin, the largest and best known occurrence in the Province, has been extensively documented elsewhere (e.g. Macauley, 1981; Macauley and Ball, 1984; Macauley *et al.*, 1985; Naylor, Prime and Smith, 1985, 1986 a,b; Kalkreuth and Macauley, 1986, in press; Naylor, Smith and Black, 1986; Naylor and Smith, 1986a,b, 1987; Naylor, Smith and Kalkreuth, 1987; Naylor, Smith and Yeo, 1987) and will not be presented here.

The following section is a summary of the results obtained by the oil shale project on the lesser known and reported occurrences of the Province which range in age from Middle Devonian to Late Pennsylvanian (Fig. 2).

MIDDLE DEVONIAN (EIFELIAN)

Oil shale occurrences within strata of the MacAdam Lake Formation were reported in the MacAdam Lake area, Cape Breton County, as early as 1891 (Neville, 1891). The occurrence was investigated by Potter (1977) by

diamond-drilling. No oil shale was intersected in the 2 diamond-drill holes. The authors, through field examination, found that exposed strata in the area comprise thin (7.5-60 cm thick), dark grey to black, laminated, silty shales containing vitrainous coaly laminae and poorly preserved plant fragments, interbedded with dark green-grey siltstone, sandstone and conglomerate. Ten samples of the shale were obtained but analytical data are not available to date.

EARLY MISSISSIPPIAN (TOURNAISIAN)

Exposures of Horton Group shale were examined at Horton Bluffs, Hants County and Big Marsh, Antigonish County. The shales at Horton Bluffs are typically dark grey, silty and micaceous. Rock-Eval pyrolysis of 4 samples show the shales to be thermally mature, contain less than 1% organic carbon and yield less than 5 l of hydrocarbons per tonne. The oil shale at Big Marsh, is typically black and massive, has a low specific gravity, resists fracture and has a conchoidal fracture style. Rock-Eval pyrolysis of 2 samples reveals the shale to be thermally mature, contain about 7.5% organic carbon and yield about 15 l of hydrocarbons per tonne. The organic component of the Big Marsh oil shales is characterized chiefly by algal detritus with minor amounts of humic material and spore and algal bodies (Kalkreuth and Macauley, 1986; in press).

¹ Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

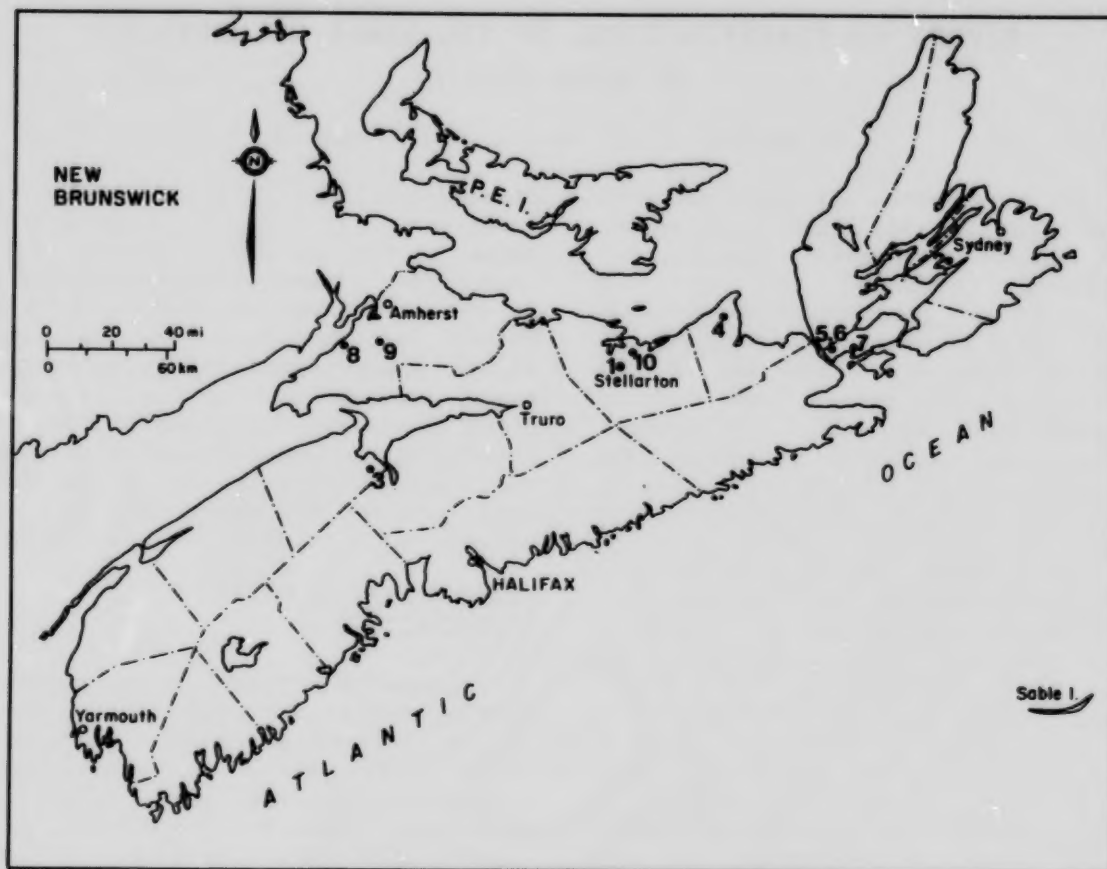


Figure 1. Location of oil shale occurrences examined by the Nova Scotia oil shale project; 1 - Stellarton; 2 - MacAdams Lake; 3 - Horton Bluffs; 4 - Big Marsh; 5 - Port Hawkesbury; 6 - Port Malcolm; 7 - Whiteside; 8 - Joggins; 9 - Styles Brook; 10 - Trenton Syncline.

EARLY PENNSYLVANIAN (WESTPHALIAN A)

Exposures of the Riversdale Group reported to contain oil shales were examined at Port Malcolm, Whiteside and Port Hawkesbury, Richmond County. Dark grey to black pelecypod-bearing shales were sampled (3 samples) at Port Malcolm and Whiteside. The shales are thermally mature, contain 3-5% organic carbon and give hydrocarbon yields of 2.5-6.0 l/t as indicated by Rock-Eval evaluation. A thin (10 cm thick) black silty shale bed was sampled at Port Hawkesbury; analyses indicate it is thermally overmature and virtually no hydrocarbons are generated from its

content of 4% organic carbon.

MIDDLE PENNSYLVANIAN (WESTPHALIAN B-C)

Strata belonging to the Cumberland Group were examined in outcrop at Joggins and in core from Styles Brook. Both areas are within the Joggins-Chignecto coalfield of the Cumberland Basin, Cumberland County. Twelve thin (10 cm thick or less) and 1 thick (up to 1.7 m thick) oil shale beds were examined at Joggins in the 330 m section below the Forty Brine Seam. The oil shales are typically black, ostracod- and pelecypod-bearing, shaly to massive, bituminous limestones and

AGE	PERIOD		STAGE	
	CARBONIFEROUS	PENNSYLVANIAN	WESTPHALIAN	STAGE
P A L E O Z O I C	C A R B O N I F E R O U S	P E N S Y L V A N I A N	W E S T P H A L I A N	Stephenian
				E
				D
				C
				Trenton Syncline ¹ Stellarton ^{2,3,4,5}
				B
				Styles Brook, Joggins ^{6,7}
				A
				Port Hawkesbury, Port Malcom, Whiteside ^{8,9}
	M S S I S S I P P I A N	S I S S I P P I A N	N A M U R I A N	Namurian
				Viséan
				Tournaisian
				Horton Bluff ¹⁰ Big Marsh ^{11,12}
	D E V O N I A N	F A M E N N I A N	F A M E N N I A N	Famennian
				Eifelian
				MacAdam Lake ¹³
	E M S I A N	E M S I A N	E M S I A N	Embian

Figure 2. Geological column showing the stratigraphic position of reported oil shale-bearing strata of Nova Scotia. Age determinations for the locations are: 1 - Dolby (1987); 2 - Dolby (1986a); 3 - Dolby (1986b); 4 - Bell (1940); 5 - Hacquebard and Donaldson (1969); 6 - Bell (1944); 7 - Hacquebard and Donaldson (1964); 8 - Hacquebard (1972); 9 - Shea and Wallace (1962); 10 - Bell (1960); 11 - Benson (1974); 12 - Boehner and Giles (1982); 13 - McGregor (1977).

organic-rich limy claystones which overlie and underlie coal seams. The section examined in the Styles Brook drillcore represents strata above the Forty Brine Seam. The oil shales are 10-20 cm thick beds of dark grey to black pelecypod-bearing and carbonaceous (coalified plant remains) shale.

Rock-Eval pyrolysis of 9 Joggins samples show that they are thermally immature to near-maturity and produce yields of 1-20 l of hydrocarbons per tonne. The organic component of the bituminous limestones is comprised predominantly of detrital vitrinite with minor amounts of algal debris and filamentous algae (W. Kalkreuth, personal communication, 1986).

LATE PENNSYLVANIAN (WESTPHALIAN D)

Strata belonging to the Pictou Group were investigated by field examination and diamond-drilling in the Trenton Syncline north of New Glasgow, Pictou County. Oil shales were identified in Smalls Brook and in 2 exploratory coreholes, P57 and P58, drilled for coal and oil shale by the Nova Scotia Department of Mines and Energy in 1986 (D'Orsay *et al.*, 1986). The oil shales, which are associated with thin coal seams, are dark grey to black and contain vitrainous coaly laminae, plant remains, pelecypods, ostracods and local fecal pellets. Hole P57 intersected 28 oil shale beds from 0.2-1.0 m (av. 0.4 m) thick at a depth of 8.2-58.4 m; the oil shale beds account for 20.9 % of the interval thickness. One oil shale bed was encountered along Smalls Brook and in hole P58 the oil shale bed was encountered at a depth of 447.53-447.64 m. Rock-Eval pyrolysis of 12 samples indicate that the shales are thermally mature (slightly), contain 4-16 % organic carbon and give hydrocarbon yields of 8.5-55.0 l per tonne. The organic component is comprised of a 3:1 admixture of algal

to humic debris.

CONCLUSIONS

The low hydrocarbon yields obtained from the above oil shale occurrences indicate they are currently unsuitable for use as a direct source of hydrocarbons. However, the occurrence of hydrocarbon shows and accumulations elsewhere in the Maritimes (e.g. Pictou Coalfield and Moncton Basin) in age-equivalent strata suggests that they may have acted as a local petroleum source rock; a potential worthy of further investigation. The attention New Brunswick oil shales are attracting, for their potential to reduce sulphur emissions during co-combustion with high sulphur Minto coal (Macauley *et al.*, 1985), suggests that some of the Nova Scotia local oil shales may warrant an assessment for similar potential.

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A SUMMARY OF RECENT RESEARCH IN THE PICTOU COALFIELD, NOVA SCOTIA¹

R. D. Naylor, W. D. Smith and G. M. Yeo²

INTRODUCTION

Despite its small size (20 km X 6 km), the Pictou coalfield was an important producer of coal for many years. This report summarizes some of the findings of recent geological research relevant to coal exploration and development in the Pictou coalfield.

STRUCTURAL GEOLOGY

Economic deposits of the Pictou coalfield are confined to the Stellarton Graben, a synsedimentary rhomb graben formed by the northeastern extension of the Cobequid Fault and the southwestern extension of the Hollow Fault. Field observations and fracture analyses show that the graben was formed by Late Westphalian dextral strike-slip along the faults in response to regional northwest-southeast compression (Yeo and Gao, 1986, 1987; Gao, 1987). This also accounts for faulting and folding within the graben. Authigenic chlorite and muscovite in the fault rocks are indicators of dynamo-thermo metamorphism.

LITHOSTRATIGRAPHY AND PALEOGEOGRAPHY

The Stellarton Group (Bell, 1940), which comprises predominantly fine grained grey clastic rocks, is restricted to the Stellarton Graben.

The group has a composite thickness of about 2600 m, as based on recent drilling. Evidence that graben infilling was coincident with graben formation includes (1) facies changes toward the graben margins, such as increase in coarse grained strata and changes in coal quality and thickness (Hacquebard *et al.*, 1967; Hacquebard and Donaldson, 1969), and (2) highly variable sediment transport directions compared to those of coeval strata outside the graben (Fralick and Schenk, 1981; Yeo, 1985).

Three phases of graben subsidence and infilling are recognized in the Stellarton Group (Yeo and Gao, in press). During each phase, lacustrine sedimentation predominated in the central part of the graben, while alluvial fan, fluvial and deltaic sedimentation occurred toward the graben margins. At the same time, lower Pictou Group sediments were deposited north of the graben from north flowing, anastomosing rivers with small lakes.

Scarcity of outcrop and lack of detailed subsurface data has long hindered the understanding of fine scale, lateral facies variation within the Stellarton Group. Recent diamond-drilling by Suncor Incorporated and detailed surface mapping (e.g. Naylor, Prime and Smith, 1986) has substantially increased the level of stratigraphic information available,

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particularly with regard to the stratigraphic complexity of the upper Stellarton Group. Naylor and Smith (1986) recognized 42 oil shale beds within the upper Stellarton Group which provides a useful framework for detailed stratigraphic analysis (Naylor, Smith and Black, 1986). Deep drilling in the central part of the graben revealed that the 14 or more coals of the middle Stellarton Group onlap toward the graben margins. The lower coals appear to be restricted to the central western part of the graben while higher seams, such as the Foord and Cage, extend further to the east than previously believed.

Environments of coal deposition in the upper Stellarton Group have been considered in some detail (Naylor, Prime and Smith, 1985; Naylor, Smith and Black, 1986; Naylor and Smith, 1987; Snow, in preparation). These authors showed that marginal alluvial fans followed by sandy deltas partially infilled lakes, gradually confining them to the basin centre. During subsequent, lengthy periods of delta abandonment peat swamps occasionally developed on the delta plain. Transgression of central basin lakes gradually drowned the peat swamps resulting in development of coal seams which thicken toward graben margins. Coal-forming environments in strata lower in the Stellarton Group were studied by Hacquebard and Donaldson (1969) and Calder (1979).

CHRONOSTRATIGRAPHY AND PALYNOLOGY

Palynological analyses were done on suites from the Acadia, Foord and McKay coals, Coal Brook Member shales and oil shales, and lower Pictou Group coals north of the graben. The analyses were used to augment earlier unpublished palynological studies by L. S. Barss and to document vertical and lateral palynofacies changes (Dolby 1986, 1987). Spore assemblages indicate that the age of the Acadia Seam is

Early Westphalian C, the Foord Seam is Late Westphalian C, and the McKay Seam is Early Westphalian D. The age of the lower Pictou Group ranges from Late Westphalian C to Westphalian D, and is therefore partly coeval with the Stellarton Group. More details are reported elsewhere in this publication (Yeo *et al.*, 1987).

COAL PETROGRAPHY AND GEOCHEMISTRY

Petrographic investigations of the Stellarton Group coals have been undertaken by Hacquebard and Donaldson (1969), Hacquebard and Avery (1976), Kalkreuth and Macauley (in press), Yeo *et al.* (1987) and Yeo *et al.* (in preparation). The coals were formed from peats which accumulated in wet forest swamp and marginal lacustrine settings subjected to cyclic drying and flooding. The coals of the Thorburn and Coal Brook Members commonly grade vertically and laterally into oil shale (Naylor and Smith, 1986). The petrography of the coal to oil shale transitions is under investigation by a variety of workers. Preliminary geochemical investigations of the coals (Birk and Pilgrim, 1986) show that although the concentrations of some metals (Zn, As, Cd, Ga and Sc) are above their Clarke values, most are lower than the Sydney Basin coals.

The rank (up to medium volatile bituminous) of coals in the Pictou coalfield has been ascribed to burial of the Stellarton Group beneath thick cover (Hacquebard, 1984). However, comparison of coalification gradients for Stellarton and lower Pictou Group coals indicate that this is not the case. The coalification gradient for Stellarton coals is much higher than that for lower Pictou Group coals of the same age. Since there is no evidence that the Stellarton Group was more deeply buried than nearby lower Pictou Group strata, it is inferred that the high rank of the Stellarton coals is due to anomalous heat flow

within the graben.

FUTURE COAL EXPLORATION AND DEVELOPMENT

Irrespective of a lengthy mining history, many coal development and exploration possibilities still remain untested within the Pictou coalfield. Recent drilling by Suncor Incorporated shows that the Foord Seam has significant potential for development east of the former workings. Naylor, Smith and Black (1986) suggested, on the basis of new paleogeographic and structural models, that undiscovered coal seams may exist within the Coal Brook Member at the eastern end of the coalfield. The McLeod and Acadia seams have also recently received considerable attention from government and industry.

Given its geographic position close to a coal-fired thermal electric plant and the low sulphur content of its coals, the Pictou coalfield remains an intriguing possibility in the search for new coal mines.

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CLASSIFICATION AND ORGANIC PETROGRAPHY OF THE OIL SHALES OF THE STELLARTON BASIN¹

R. D. Naylor, W. D. Smith and W. D. Kalkreuth²

SUMMARY

Three macroscopically distinct types of organic-rich rocks have been described historically as oil shales within the Stellarton Basin. This report proposes a revised classification of these rocks based on their organic petrography.

The first rock type is a black subfissile shale with an average total organic carbon (TOC) content of 6%. These subfissile shales represent in excess of 90% of the total volume of oil shales within the basin. Figure 1a illustrates the average volume percent of the various macerals which constitute the organic component of the subfissile shales. An average lamalginite content of 73% allows the subfissile oil shales to be classified technically as lamosites (Cook, Hutton and Sherwood, 1981). The term alginite-bearing shale is favoured by the authors however, due to the poorly preserved nature of the lamalginite macerals and a dissimilarity in hand specimen to lamosites as represented by the Albert oil shales of New Brunswick.

The second rock type is black, relatively organic-rich (av. 25% TOC) and massive, has a low specific gravity, and breaks with a conchoidal fracture. This lithology has been referred to commonly as torbanite, by its physical similarity to previously designated torbanites. However,

organic petrography indicates that its organic component is comprised of 66% (av.) detrital vitrinite (Fig. 1b) which is not consistent with the petrography of a torbanite defined to be comprised primarily of the alginite maceral telalginite (Cook, Hutton and Sherwood, 1981). On the basis of high vitrinite content and the detrital nature of the vitrinite, the "torbanites" of the Stellarton Basin are actually cannel shales. The relatively low average TOC content (25%) and low volume percent of organic matter favours the use of the term cannel shale to cannel coal.

The third lithology is an oil shale forming a 1-2 m interval underlying the Oil Coal seam of the Albion Member. It also comprises 1-2 m intervals of the number three and four oil shale units of the Thorburn Member. A brownish black color and a powdery pale yellow streak are characteristic of this lithology that is locally referred to as "stellarite". Hand specimens from the Oil Coal seam commonly have a contorted broken surface. The contorted appearance may be due to bioturbation by roots associated with vegetation that was incorporated into the overlying coal seam. Very small yellow ellipsoidal "grains", which may be fossilized algal materials, are visible with a hand lense. "Stellarite" also exhibits pale yellow fluorescing bands under ultraviolet light.

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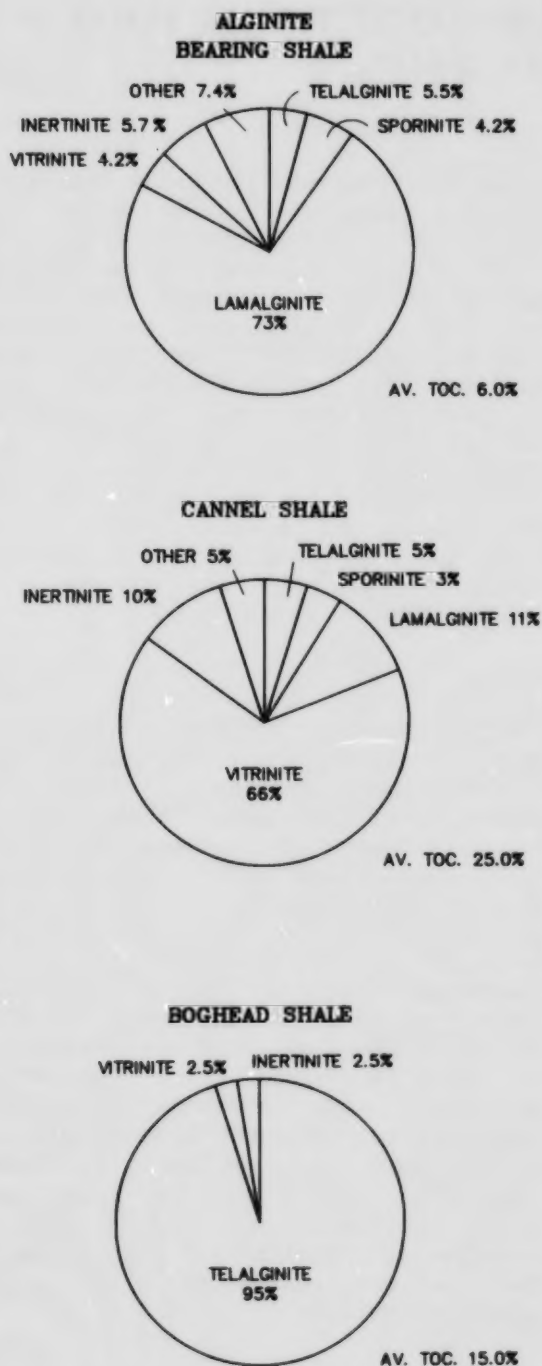


Figure 1. Average maceral analysis and TOC content of oil shales of the Stellarton Basin

The organic component of "stellarite" is almost exclusively composed of the alginite maceral telalginite (Fig. 1c). Telalginite is recognizable under fluorescent light as brightly fluorescing ovate bodies of which an internal structure is occasionally discernible. Telalginite is the principal maceral of boghead coals which are also referred to as torbanites. However, true torbanites such as those of New South Wales, Australia, have a TOC content of 40-88% with 40% considered low for a torbanite. Although "stellarite" has a maceral assemblage similar to torbanite, the average TOC content is 15% and therefore the term boghead shale will be used to describe this lithology.

Table 1 presents a summary of the historical terminology and suggested revisions as applied to the oil shales of the Stellarton Basin. The use of organic petrography provides a method of classification superior to conventional hand specimen description. The adoption of the revised terminology in Table 1 should aid when comparing the oil shales of the Stellarton Group with oil shale occurrences in other areas.

Table 1. Revised terminology for oil shales of the Stellarton Basin

REVISION BASED ON:	
HISTORICAL TERMINOLOGY	ORGANIC PETROGRAPHY
Subfissile oil shales	Alginite-bearing shales
Torbanite	Cannel shale
Stellarite	Boghead shale

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MINERAL EXPLORATION MONITORING

P. McCulloch

Monitoring of mineral exploration and development activity in Nova Scotia is carried out by the Resource Geology Section of the Mineral Development Division of the Nova Scotia Department of Mines and Energy (NSDME) and is co-ordinated through the regional office at Stellarton.

The program of exploration monitoring consists of regular visits to exploration and mining development sites as well as visits to company offices established in the Province. This provides a direct liaison with industry personnel through which the Department is able to maintain an awareness of current exploration and development activities. Additional responsibilities of the monitoring staff include a review of assessment work submitted by industry, various statistical studies on exploration expenditures and claim holdings in the Province, and preparation of information packages of non-confidential information as requested by industry personnel and the general public.

A brief outline of the various exploration and development projects undertaken in the Province is summarized on an annual basis for inclusion in the Report of Activities and the Annual Report produced by the NSDME. In addition, details on current mineral exploration are presented at the annual Open House and Review of Activities either through poster displays or presentations by Department geologists.

Detailed summaries of current exploration and development projects are also prepared on an annual basis for inclusion in reports to the Legislative Committee on Mines and

Energy and for general in-house reference as required. These summaries are non-confidential and include historical information on presently explored properties, the current status of license holders, claims and company(s) involved, and a brief summary of the work performed.

Exploration for gold continued to highlight exploration activities in the Province during 1987 with several projects advancing to various phases of development work. Exploration activities concentrated primarily on the historical gold mining districts hosted by the Cambro-Ordovician metasedimentary rocks of the Meguma Group throughout southern mainland Nova Scotia. Gold exploration focused to a limited extent on Cambrian and Hadrynian rocks of northern mainland Nova Scotia and Cape Breton Island. In addition, exploration for other commodities including limestone, gypsum and coal continued in several areas of the Province with several projects undergoing development work.

A number of new and continuing exploration programs for gold has resulted in the delineation of several deposits containing geological reserves of ore grade material in the range of approximately 1-3 million tonnes (1-3 million tons). Seabright Resources Incorporated continued underground development work on the Beaver Dam property in Halifax County where recent drilling encountered ore grade material to a depth of 600 m. Proven reserves stand at 1.08 million tonnes (1.1 million tons) grading 8.3 g/tonne (0.27 oz/ton). The company is also continuing underground development work on the Forest Hill property in Guysborough County. Work to date has delineated 1.48 million tonnes (1.5

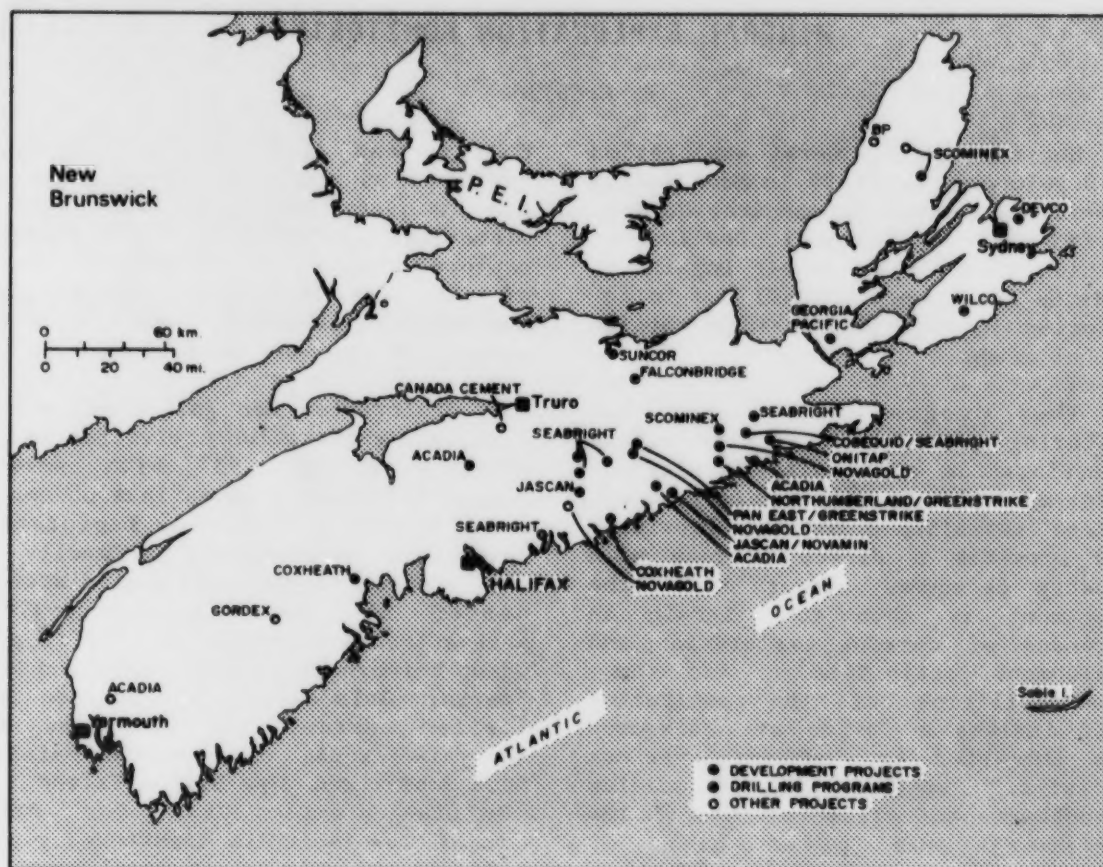


Figure 1. Location of principal exploration and development projects in Nova Scotia, 1987.

million tons) of ore grade material from several parallel veins with proven reserves just under 393 600 tonnes (400,000 tons) grading 14.7 g/tonne (0.48 oz/ton). A ramp was started to facilitate bulk sampling in another area of the property. Seabright recently acquired the Caribou gold property in Halifax County and have initiated a detailed underground exploration program to evaluate previously inferred ore reserves. Coxheath Gold Holdings Limited began an underground exploration and development program on the Tangier gold property early in the year to examine several veins returning ore grade values from surface drilling. Inferred reserves of

1.9 million tons grading 8.27 g/tonne (0.27 oz/ton) were outlined.

Acadia Mineral Ventures Limited continued a large-scale diamond-drilling program on the Mooseland gold property in Halifax County. Drill indicated reserves estimated at 492 000 tonnes (500,000 tons) grading over 6.1 g/tonne (0.2 oz/ton) were outlined and plans are to go underground on the property in the near future. An extensive diamond-drilling program is continuing on the Fifteen Mile Stream property by Pan East Resources Incorporated with preliminary estimates of ore reserves at 590 400 tonnes (600,000 tons) grading 7.4 g/tonne

(0.24 oz/ton). The company plans to go underground on the property following the completion of additional drilling.

Drilling programs are complete or are currently underway on a number of other gold properties throughout the Meguma (Fig. 1). Large-scale regional

exploration programs for gold were carried out by Seabright Resources Incorporated in several areas of the Meguma Group in Halifax and Guysborough Counties. SCOMINEX also continued an extensive regional exploration program for gold in the Precambrian complex of the Cape Breton Highlands.

DRILL CORE LIBRARY¹

J. C. McMullin, J. D. Langille, D. Murphy, W. Palmer and D. Weir

The Nova Scotia Department of Mines and Energy (NSDME) maintains core storage facilities at 4 locations: 2 at Stellarton, Pictou County, 1 at Debert, Colchester County and 1 at Malagawatch, Inverness County (Fig. 1). All facilities are full, and work is in progress to remedy this situation by selectively disposing of surplus core and constructing an additional building at the main facility in the Stellarton Industrial Park. These projects are

funded by NSDME under the Canada - Nova Scotia Mineral Development Agreement. Mr. Bill Palmer, project geologist and Mr. Donald Weir, mineral technician, are continuing a program of core reduction by evaluating drill core from areas of high density drilling. During 1987 a large package of core from the Walton mine was completed and an evaluation of the Loch Lomond area was begun.

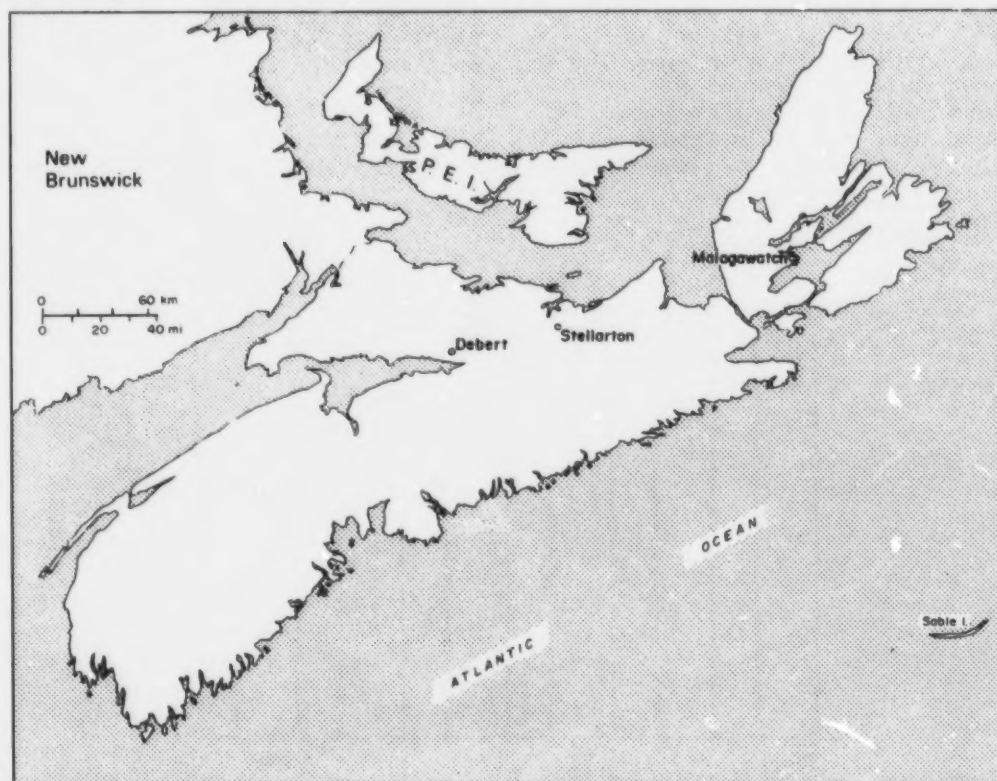


Figure 1. Locations of the core storage facilities

¹ Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

The fourth building at the Stellarton Industrial Park facility was under construction during the summer of 1987. This building will provide storage space for an additional 76 000 m (250,000 ft) of drill core and additional heated core viewing laboratory space and office space for core library personnel.

The majority of core is stored on pallets. Transfer of pallets to viewing areas is by propane powered fork-lift truck. Sampling of core is by prior permission only and is restricted to previously unsampled core. No whole core sampling is permitted. Core splitters and diamond saws are available to cut samples and a

binocular microscope and ultra-violet light are also available for visitors' use. A complete set of assessment reports on microfilm was purchased in 1987 for the use of core library visitors and staff. Photographic apparatus will be acquired this year. Currently fees are charged only for use of the diamond saws.

Not all facilities are staffed on a full-time basis so visitors are advised to contact personnel of the Mineral Development Division at the Stellarton regional office (752-8429) or at the Stellarton Industrial Park location (752-4842) at least one day prior to arrival, to arrange an appointment.

INDUSTRIAL MINERALS¹

J. H. Fowler

The term industrial minerals is used to include numerous rocks and minerals that can be divided into two general classifications, namely (1) non-metallic mineral or commodities and (2) structural materials. Industrial mineral mining in Nova Scotia has been ongoing for more than two centuries. Nova Scotia, being rich in industrial mineral resources and having excellent deep water harbours, has developed a tradition of mineral exportation to markets in many regions of Canada, United States, the Caribbean, Western Europe, the Middle East and Japan.

In the Province there are 18 industrial mineral producers operating at 27 sites producing 10 commodities

which include anhydrite, barite, clay and shale, dolomite, gypsum, limestone, salt, silica sand, building stone and peat moss. The numerous aggregate producers, operating in both granular and bedrock deposits, meet all provincial requirements with 2 companies supplying aggregate materials to expanding export markets.

The total value of industrial mineral production in Nova Scotia was \$159 million in 1986 (Fig. 1). A record production was recorded for gypsum and anhydrite at 6.3 million tonnes which was up 3.3% over 1985. Salt production showed an increase of 6.7%, sand and gravel was up 2.2% and peat moss recorded the largest

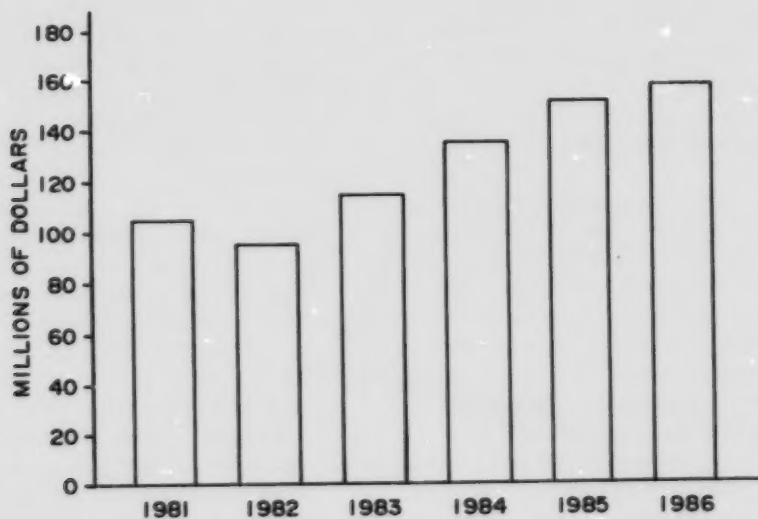


Figure 1. Value of industrial mineral production, 1981-1986

¹ Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

production increase of up 30% over the previous year.

While some of the deposits in the Province have been producing for more than 200 years, other have experienced intermittent activity. Current mining activity ranges from low level seasonal production for some commodities to high level, year round production and shipping for others. Due to changes in the international market place, new opportunities exist to (a) increase exports and diversify production for many commodities currently mined, and (b) develop other deposits considered previously to have no or restricted market potential. In light of the aforementioned the Mineral Development Division is operating 6 industrial mineral resource programs designed to create an awareness of the industrial mineral resources of the Province and to promote resource development and production diversification. These programs are funded through the Canada - Nova Scotia Mineral Development Agreement.

Programs underway include:

1. a project to identify and promote the development of the building stone resources of the Province;
2. a program to document the gypsum and anhydrite resources of Nova Scotia, and to identify new uses for these commodities;
3. an aggregate resource mapping project in selected regions of the Province;
4. a program to evaluate the diatomite resources of the Province;
5. a filler and extender market and resource evaluation study; and
6. an evaluation and information database collection for many of the lesser known industrial minerals in the Province. These

programs are described in subsequent papers by the project managers.

ADDITIONAL ACTIVITIES

The following industrial mineral contracts are funded by Mineral Policy Sector of Energy Mines and Resources, Canada under the Canada - Nova Scotia Mineral Development Agreement:

1. Atlantic Canada Offshore Minerals. This study is designed to identify, acquire and compile a comprehensive index on the offshore mineral resources potential for the Provinces of New Brunswick, Nova Scotia, Prince Edward Island and Newfoundland. The contract for this study was awarded to Earth and Ocean Research Limited of Dartmouth, Nova Scotia.
2. Feasibility Study - Dredging Big Bras d'Or Channel. This study is designed to determine the feasibility of dredging a section of Big Bras d'Or to allow larger shipload movements by existing and potential industrial mineral producers. This contract was awarded to Whitman Benn and Associates Limited of Halifax, Nova Scotia.
3. Industrial Mineral Markets, East Coast United States. This study will identify markets in the Eastern United States for industrial minerals that can be supplied from deposits in Nova Scotia, New Brunswick and Newfoundland. This study was awarded to Metals Economics Group.
4. Underground Storage Capability of Nova Scotia Salt Deposits. This study is designed to determine the storage capability of selected salt deposits in Nova Scotia. The contract was awarded to Nolan Davis and Associates of Halifax.

GYPSUM/ANHYDRITE PROJECT¹

G. C. Adams

Three goals were established for the Gypsum/Anhydrite Project:

- to produce a comprehensive mineral inventory of the gypsum and anhydrite resources of Nova Scotia,
- to increase and enhance relations between the Nova Scotia Department of Mines and Energy (NSDME) and

the Province's present producers, and to initiate and encourage the development of alternative utilization of the gypsum and anhydrite resources of Nova Scotia.

At the time of writing, compilation of the field occurrences in

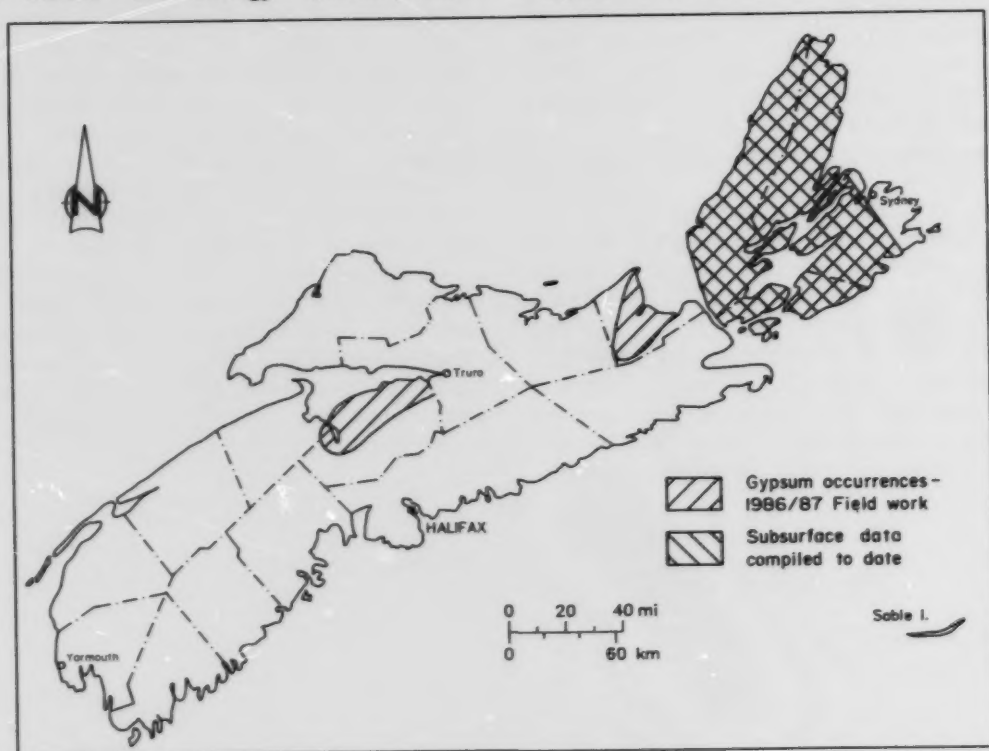


Figure 1. Gypsum/anhydrite project fieldwork

¹ Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

Cape Breton, Inverness, Richmond and Victoria Counties on Cape Breton Island and in Antigonish and Hants Counties on the mainland were virtually complete (Fig. 1). During the summer of 1987, >200 hand specimens were collected and 652 samples were taken from drill core stored at the NSDME drill core library at Stellarton.

Subsurface information gleaned from assessment reports and the annual report, *Drilling Logs of the Government Core Drills*, was studied during the winter of 1986-87. Investigation of this information, in conjunction with data gathered during the 1986 field season, has resulted in the delineated of several interesting subsurface areas in Cape Breton, Hants and Richmond Counties.

Gypsum production in Nova Scotia continued to maintain record levels through 1986 and into 1987. As a result, interest in the gypsum resources of Nova Scotia by current producers and outside parties remains high. Two of the four major gypsum producing companies, mainly Little Narrows Gypsum and Georgia Pacific

Corporation, have presently opened new quarries and a third company, Fundy Gypsum, is drilling an area of potential outside of its present quarry area. Nova Construction plans to begin shipping gypsum from its small quarry at Brierly Brook in the fall of 1987 and Domtar Construction Materials is presently investigating the possibility of reopening an old quarry at Baddeck.

Research, funded through the Canada - Nova Scotia Mineral Development Agreement, is currently underway at the Technical University of Nova Scotia to determine whether anhydrite from several localities in the Province can be used in coal mine roadside packing systems. This research may lead to additional research into other anhydrite applications. In addition, indirect assistance has been given to ongoing research at the Nova Scotia Agricultural College in Truro where studies to determine the benefits of gypsum as a manure amendment are presently underway. Results from these two studies will be available in the near future.

AGGREGATE RESOURCE OF NORTHERN NOVA SCOTIA¹

G. Prime

Aggregate deposits in Cumberland and Colchester Counties vary considerably in terms of their quality, extent and accessibility. Producers and users in many localities are seeing a depletion of sources while others are facing competition for the resource land use. Some areas lack entirely any amount of quality aggregate materials. Overall, consumption has remained

relatively strong and known reserves are limited at present. To address these problems, a resource inventory and evaluation program for northern Nova Scotia was created and is funded under the Canada - Nova Scotia Mineral Development Agreement.

The initial field season of the project in 1986 involved mapping the

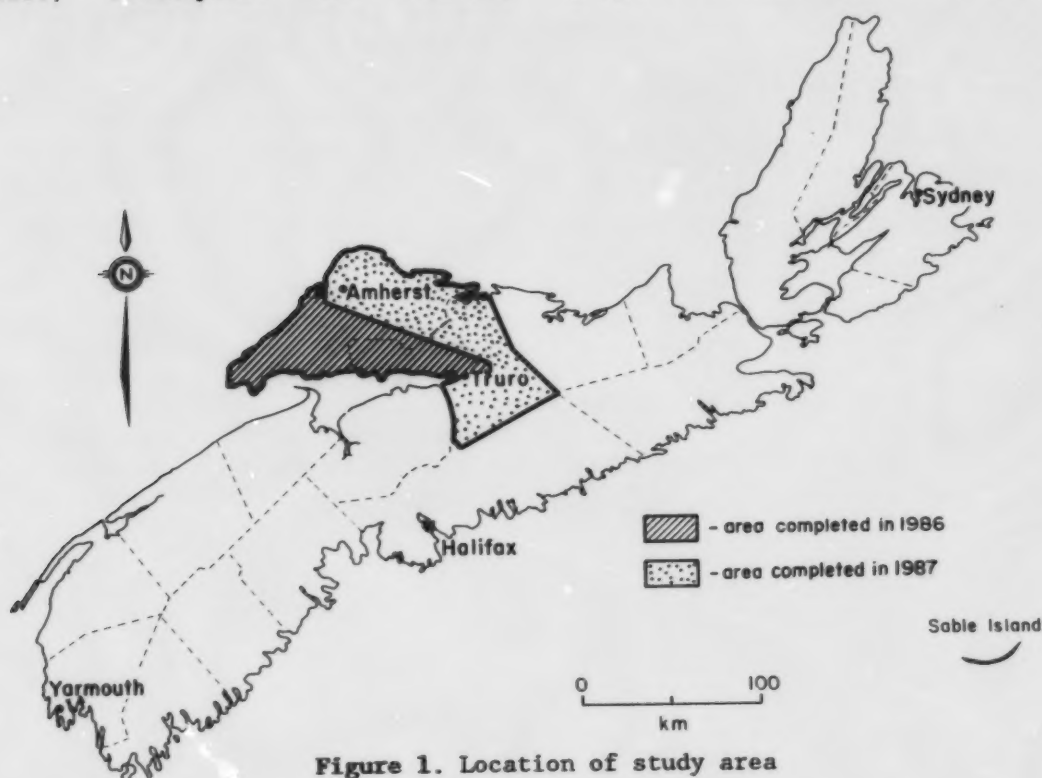


Figure 1. Location of study area

¹ Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

western half of the study area (Fig. 1). The procedure consisted of the examination of all granular aggregate exposures with particular emphasis on sand and gravel pits. The fieldwork, in conjunction with aerial photographic interpretation, permitted accurate delineation of the deposits, including the identification of new ones. Bedrock exposures were examined in areas where granular materials were either of poor quality or absent. Weathered bedrock materials which exist at the surface in an unconsolidated state were included.

The 1987 field season saw the conclusion of the field phase of the

project. During this period the eastern half of the study area was field mapped (Fig. 1). In addition, a comprehensive sampling program was conducted over the entire study area concentrating on the more promising deposits. More than 100 samples were taken from pits and other exposures and will be tested for quality and size fraction.

The remainder of the project will be spent assessing the data and preparing a report and maps. If time permits, newly identified deposits will be examined in more detail.

FILLERS AND EXTENDERS PROJECT¹

P. Luke

The Fillers and Extenders Project was initiated in August 1986 as a Canada - Nova Scotia Mineral Development Agreement program to investigate local and international filler markets and to identify filler grade deposits in Nova Scotia.

The project included a market study of local industries that manufacture products requiring filler and extender materials. Once contact was made with industry representatives and quantities and specifications of filler materials were identified, the next step was to investigate indigenous materials as possible substitutes.

Due to the highly competitive nature of the filler industry, a deposit must possess material of high quality with good reserves, and offer easy accessibility to its eventual marketplace.

After initial field investigations it was apparent that possibly 5 or 6, of the occurrences and deposits

visited, have potential for filler and extender application. At present, each of these are being examined more closely. The Glencoe limestone deposit is particularly interesting as it has zones that seem to meet market requirements. Drilling should delineate a zone of white, high quality calcium carbonates.

Other commodities under investigation include white marble at Marble Mountain in Inverness County, which will also be drilled this year,

kaolinitic clay at Hardwood Lands in Hants County, muscovite at Mica Hill in Victoria County, and barite at Scotsville in Inverness County.

During the past summer, a scale model of the Glencoe limestone deposit was assembled as a promotional aide. Vertical plexiglass panels exhibit drillhole information delineating various grades of limestone (i.e. metallurgical, cement and filler grades).

¹ Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

DIATOMACEOUS EARTH PROJECT¹

A. R. (Sandy) Anderson

Diatomaceous earth or diatomite is a siliceous sedimentary material which throughout Nova Scotia is commonly found in lakes and bogs in the upper reaches of many watersheds. It is formed by the accumulation of the skeletal remains or shells of tiny one-celled plants known as diatoms. The

material is composed of hydrous silica ($\text{SiO}_2 \cdot \text{H}_2\text{O}$) that is characterized by a low specific gravity, large surface area and high porosity. In pure form, it is generally snow white however, in situ, impurities often give it an orange or green colour.

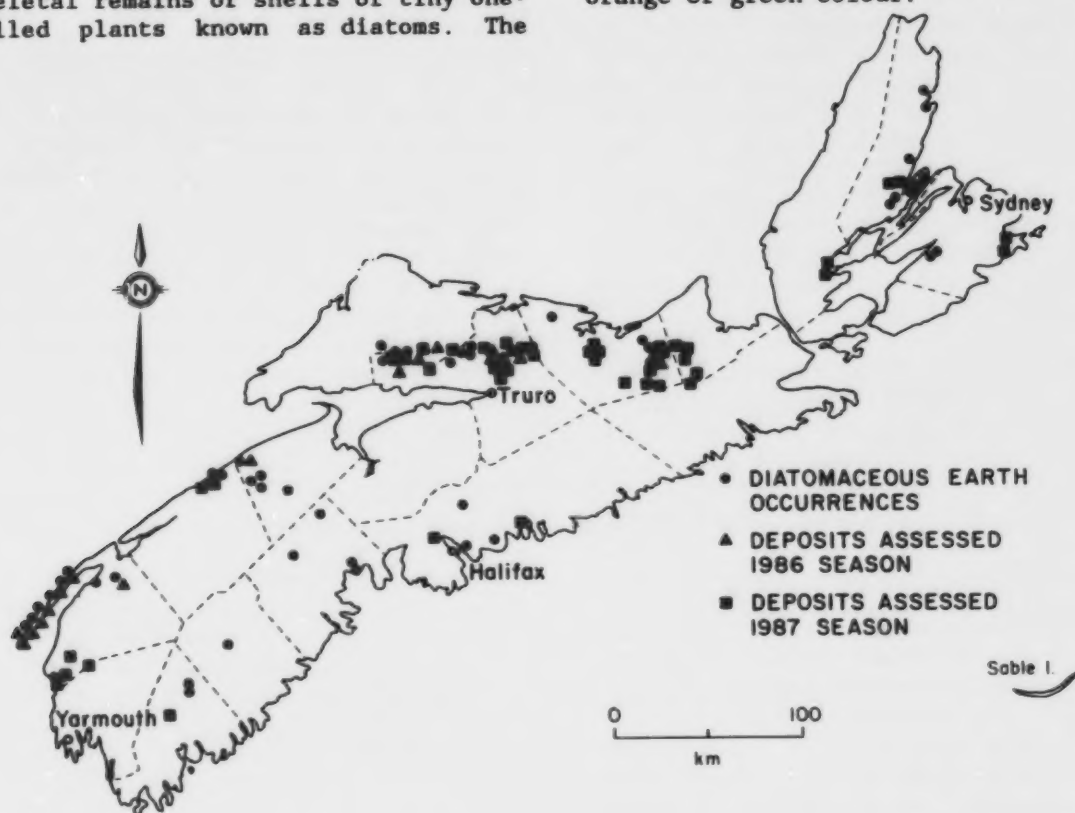


Figure 1. Locations of diatomaceous earth occurrences and deposits in Nova Scotia

More than one half of a million tonnes of diatomite is used annually as a filter aid acting as a filler or

extender in many products such as paints, plastics and paper. It can also be used as an absorbent, chemical

¹ Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

carrier insulation and an additive to concrete mixtures (pozzolan).

Diatomaceous earth was mined at several locations in Nova Scotia from 1928. In 1952, 11 800 tonnes of semi-processed diatomite was produced from 3 sites namely Little River in Digby County, and Oxford (Castlereagh) and New Annan (Rhudle Pond) in Colchester County. The uses for the product were as a mild abrasive, insulation material in firebrick and a filler in rubber products. As markets changed and the production of high quality diatomite at low cost increased in the southern United States, production in Nova Scotia ceased. However, increasing transportation costs, new products and expanding markets have kindled a new interest in the local deposits of diatomite.

Forty-four deposits of diatomite were evaluated and sampled during the 1987 field season (Fig. 1, Table 1).

These deposits are located Province-wide and vary significantly in size and quality of diatomite resource. The best deposits are located beneath shallow waters in lakes and ponds at the head of watersheds. The purest deposits are usually beneath one metre of water near springs or groundwater sources. The diatomite varies in colour from a dark grey brown, semi-gelatinous, amorphous ooze to a white, solid, clay-like sediment; the latter is the purest (> 1-2% organics).

Location and assessment of the diatomite deposits involved the use of a boat- or canoe-based raft with a drilling platform from which samples of the sediment were taken using a 50 cm MacAulay auger and a 1 m Hiller auger. The depth, ariel extent and quality of material of each diatomite deposit was tested. Quality analysis is based on whole sediment analyses, particle size distribution, total organics and moisture content.

Table 1. Diatomite occurrences in Nova Scotia

County	Occ/ Dep ¹	1986	1987	Sites ²
Yarmouth	1	-	-	-
Digby	14	8	4	72
Queens	2	-	1	1
Shelburne	5	-	2	2
Kings	6	-	1	1
Annapolis	3	-	2	2
Lunenburg	4	-	2	2
Halifax	4	-	2	2
Cumberland	7	1	2	3
Colchester	37	12	11	23
Pictou	18	1	7	8
Antigonish	5	-	5	5
Guysborough	0	-	-	-
Cape Breton	4	-	2	2
Richmond	-	-	-	-
Victoria	1	-	-	-
Inverness	10	-	3	3
Hants	1	-	-	-
TOTAL	122	22	44	126

¹ Occ/Dep = occurrence or deposit

² Sites = total sites investigated

BUILDING STONE PROJECT¹

G. B. Dickie

INTRODUCTION

The use of natural stone in building construction is increasing in the major industrialized nations of the western world. The reasons for this trend are reported to be due to (1) reduced costs of finished stone products due to improvements in cutting and polishing technology and (2) architectural trends away from steel and glass exteriors and toward combinations of brick, natural stone and glass. In response to the increasing demand for information on building stone deposits, the Building Stone Project, funded under the Canada - Nova Scotia Mineral Development Agreement, was initiated in September 1985 as a 5-year program to identify and evaluate the building stone deposits of Nova Scotia. Two years of field work have been completed with positive results (Fig. 1).

Four sandstone deposits have been tested by diamond-drilling. One granite deposit has been diamond-drilled and bulk sampled for the test production of cladding panels and street curbing. Several granite deposits on tide water have been evaluated for aggregate and crushed stone production. A marble deposit on Cape Breton Island will be drilled in the fall of 1987 for evaluation as a possible building stone resource. Promotional information on the stone deposits outlined to date and a sample catalogue including sandstone and granite are in preparation.

SANDSTONE DEPOSITS

The red sandstone deposit at Amherst in Cumberland County was diamond-drilled in 1986 and an open reserve of 70 000 tonnes of high quality stone was outlined. The reserve of olive green and blue sandstone of the Wallace Quarry in Cumberland County was extended to 26 000 and 84 000 tonnes, respectively. A deposit of 66 000 tonnes of grey sandstone was outlined at Eight Mile Brook in Pictou County and 10 000 tons of brown sandstone was drilled at Sawmill Brook in Pictou County.

A sandstone deposit located at Hardwood Hill, Pictou County was evaluated for use in the common user dock construction project for the Town of Pictou. A new quarry was opened at this site in July 1987.

GRANITE DEPOSITS

Field work in 1987 has concentrated on locating granite deposits suitable for building stone. To date, approximately 12 old quarries and new sites have been evaluated. The Terence Bay deposit has been diamond-drilled and a new quarry site has been identified. In addition, 5 large granite blocks were taken from the deposit for the preparation of full size specimens of cladding panels, street curbing and a finished monument. The results of this work indicate that the Terence Bay stone has excellent characteristics for use as building stone.

¹ Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

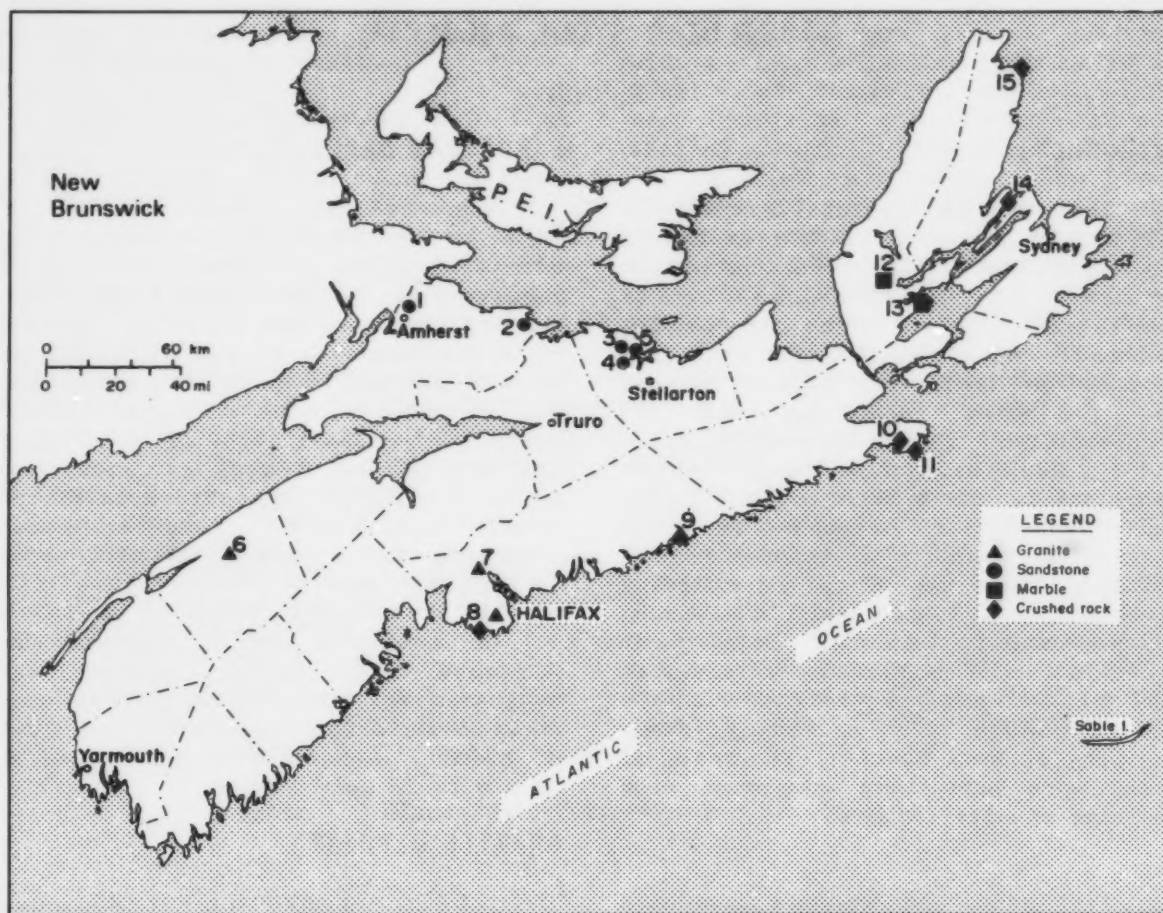


Figure 1. Building stone deposits of Nova Scotia. 1. Amherst Quarry; *2. Wallace Quarries Limited; *3. Hardwood Hill; 4. Eight Mile Brook Quarry; 5. Sawmill Brook Quarry; *6. Heritage Memorials; 7. Quarry Lake; 8. Terence Bay; 9. Sheet Harbour; 10. Flagstaff Hill; 11. Port Howe; 12. Glencoe; *13. Marble Mountain; 14. Kellys Cove; 15. White Point (* Producer).

POTENTIAL CRUSHED STONE DEPOSITS

Six areas, underlain by granite rocks, have been identified as potential crushed stone deposits located on 12 m minimum tidewater. The sites are (1) Kelly Cove, Victoria County, (2) White Point, Victoria County, (3) Flagstaff Hill, Guysborough County, (4) Port Howe, Guysborough County, (5) Sheet Harbour, Halifax County (quartzite) and (6) Terence Bay, Halifax County. Additional information

will be supplied on these deposits in a separate open file release.

PROMOTIONAL MATERIAL

A preliminary report on the sandstones of Nova Scotia is in progress and will be available in 1988. A sample catalogue and brochure is in preparation and will be completed in 1988. The catalogue will include sandstone, granite, marble and slate rock specimens, and information about

specific deposits and test results in a format to which additions can be made as new deposits are identified.

VARIOUS COMMODITIES PROJECT¹

R. MacDonald

The Various Industrial Mineral Commodities Project was initiated in May 1986 to update and increase the database on several industrial mineral commodities which occur throughout Nova Scotia. The commodities with the best potential for development as indicated by market demand, have received the most attention. These commodities include limestone, dolomite, silica, barite, garnet, graphite, fluorite, celestite, andalusite, wollastonite, topaz and others that may arise as market demands change.

After an initial period of data compilation and field investigations, several deposits have been isolated for more detailed work. The high grade silica and garnet deposit at Chegoggin Point, Yarmouth County is presently under closure and an exploration program is ongoing to determine the size and quality of this excellent geographically located deposit. Field investigations followed by geophysical surveys have located drill targets which are being diamond-drilled to determine the size and orientation of this deposit. Previously reported work indicated widths of +70 m of silica grading 98-99% SiO₂ for extended areas. The main purpose of the present infill drilling program is to determine whether the deposit is continuous along strike as indicated by the previous drilling programs. A report will follow the completed work program and the property will be opened for tenders.

Detailed field investigations on

several limestone and dolomite deposits throughout the Province will be followed by drilling programs on selected deposits. One limestone quarry has been established due to these investigations, and private sector exploration and development work is ongoing at several others. Similar field investigations on a number of barite deposits will be followed eventually by a drilling program on one deposit.

Other commodities investigated to date include:

- . alumina deposits in Guysborough County,
- . mica deposits throughout the Province,
- . titanium-rich sand deposits along the mouths of some provincial rivers,
- . graphite deposits throughout the Province, and
- . a variety of commodities that result as a by-product of present mining operations within the Province.

A site is being prepared adjacent to the Nova Scotia Department of Mines and Energy Core Library facility in Stellarton at which bulk samples of each of the various, high interest commodities can be stored and made readily available to anyone requesting samples for testing. It is hoped this arrangement will help the promotion of industrial commodities in the Province by making such samples available throughout the year.

¹ Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

MINERAL INVENTORY

N. A. Lyttle

BIBLIOGRAPHIC DATABASE ACTIVITIES¹

(J. Gillespie-Wood, K. Lindgreen, R. Hicks and B. Hawkins)

Indexing and on-line data entry into GEOSCAN continued throughout 1987 for Nova Scotia Department of Mines and Energy (NSDME) bibliographic records. GEOSCAN is a bibliographic database which provides access to publicly available geoscience literature concerning the Canadian landmass and offshore regions. The database presently contains over 114,750 records and is co-operatively produced from the indexing contributions of 15 federal, provincial and professional geoscience organizations located throughout Canada. The Geological Survey of Canada, through the National GEOSCAN Centre, co-ordinates these indexing activities and provides computer resources in support of this project.

In 1987, 910 new NSDME records were added to GEOSCAN. These records consisted of 321 assessment reports, 170 open file maps, 70 open file reports, 153 publications and 196 journal literature references, representing a 10.5% increase in the Nova Scotia component of the database. As of August 31, 1987, the database contained 9,594 NSDME records consisting of 4,239 assessment reports, 1,794 publications, 1,254 journal literature references, 920 open file maps, 790 open file reports and 597 theses.

A new 5-year bibliographic index, entitled Report 86-4: *Index to Publications, Open File Reports, Open File Maps and Theses 1981 to 1985* is completed, and will be published in the latter part of 1987. In addition, Report 87-3: *Index to Assessment Reports, Publications, Open File Reports and Open File Maps for 1986* has been completed, and will be published in the latter part of 1987.

Throughout the summer and fall of 1987, a project was undertaken to index all available onshore and offshore petroleum assessment reports on Nova Scotia that had not been previously indexed. A total of 84 onshore reports were indexed and will be publicly available on microfiche when their confidentiality periods expire within the next 5 years. Microfiche copies of reports on 108 offshore wells have been ordered from the Canadian Oil and Gas Lands Administration (COGLA) in Ottawa, and will be available for consultation in the Halifax library of the Department. When indexing is completed on the offshore reports, it is anticipated that an index of onshore and offshore petroleum assessment reports for Nova Scotia will be published.

MINERAL OCCURRENCES DATABASES ACTIVITIES²

(G. DeMont)

The Metallic Mineral Occurrences database presently contains 1,053

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mineral occurrence records, consisting of 273,000 bytes of data, and the Industrial Mineral Occurrences database presently contains 1,076 records, consisting of 263,000 bytes of data. These databases are presently running on dBASE III PLUS, and copies of portions of these databases (by map sheet), or custom searches, can be obtained on diskette upon request.

In an effort to improve the quality and reliability of the data in the Mineral Occurrences database, a program of systematic reference researching and checking, coupled with selected field checking, was initiated in 1987. The field checking was greatly aided by the efforts of K. Northcote of NSDME and A. Sangster and W. Ervine of the Geological Survey of Canada. Eighty-six metallic mineral occurrences were researched on map sheets 11E/08, 11E/09, 11E/15, 11E/16, 11F/05, 11F/16, 200/09 and 200/16, resulting in the revision of 76 mineral occurrence data cards, and the elimination of 10 cards as legitimate metallic mineral occurrences.

DRILLHOLE DATABASE ACTIVITIES²

(G. DeMont)

A project was initiated in the summer of 1986 to add to the database all the drillholes reported in the NSDME publications Drilling Logs of

Government Core Drills, which are available from 1901 to 1985. Approximately 6,000 drillholes have been coded to date, extending from 1985 back to 1957. The Drillholes database presently contains 17,214 drillhole records consisting of approximately 6 megabytes of data. The database is presently running on dBASE III PLUS, and copies of portions of the database (by map sheet), or custom searches, can be obtained on diskette upon request.

GOLD BIBLIOGRAPHY ACTIVITIES

(J. Gillespie-Wood)

Compilation of information for the gold bibliography, entitled *Report 87-2: Gold in Nova Scotia: a Bibliography of the Geology, and Exploration and Mining Histories from 1832 to 1986*, is completed and publication is expected in the latter part of 1987. The bibliography, over 500 pages in length, will contain more than 1,300 references documenting over 300 gold districts and occurrences. The bibliography will be organized into 3 parts: Part I will be an alphabetic author index; Part II will be an index by gold occurrence, with each gold occurrence subdivided into an author index, an assessment report index, and a map and cross-section index; and Part III will contain cross reference lists by gold occurrence, claim reference map, county, status, metallic mineral occurrence card number, and production figures.

² Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

GOLD INVENTORY PROJECT¹

C. Miller

SUMMARY

The objective of the Gold Inventory Project is to produce a comprehensive geological compilation and review of the distribution and character of gold and other precious metals known to occur in the Nova Scotia. The diversity of geological environments in which precious metals are located and the economic potential of each will be demonstrated.

Phase one and two of the project

are complete. In phase one, more than 2000 references and articles on precious metals in Nova Scotia were reviewed. In phase two, selected well known and little known occurrences were located, described and sampled to verify and(or) update old information sources.

Phase three of this project is the compilation of a final report and accompanying maps expected to be completed by late 1987.

¹Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

MINERAL LAND USE POLICY DEVELOPMENT¹

D. B. Hopper and C. A. Dobson

LAND USE PROJECT

The Nova Scotia Department of Mines and Energy (NSDME) is progressing well with a comprehensive mineral land use planning project. The goal of the project is to provide information needed to formulate a Mineral Land Use Policy aimed at ensuring the protection, conservation and proper management of the mineral and energy resources of Nova Scotia. Mapped and written information will be compiled for use by the provincial and municipal planning community to benefit the decision-making process in land use planning.

The objectives of the project include:

- . compilation of mineral and energy resource information,
- . promotion of the use of this information by those involved in land use planning and resource management,
- . identification of planning issues associated with the protection and use of mineral and energy resource lands, and
- . encouragement of the protection of mineral and energy resource lands against conflicting land use.

The project has 3 phases. The initial phase, in progress, is an information gathering stage resulting in the compilation of maps and handbooks for each of the 18 counties. These products will provide the planning community with clearer, more accessible information on the mineral

resources of the Province. The second phase will involve creating mineral potential maps for larger regions of the Province. Such data are essential in supporting efficient, economic and safe utilization of land, mineral, fuel and water resources, especially in view of the potential multiple use of these resources by the various sectors within Nova Scotia's planning jurisdictions. The last phase which will begin once the information base has been constructed, involves the development of a Mineral Land Use Policy. The intent of any land use policy developed at the provincial level under the Planning Act shall be carried out in all applicable Municipal Planning Strategies.

The Land Use Project is co-ordinated by a staff of 2 land use planners. After a period of preliminary research and preparation, the planners have concentrated on the Mineral Resource Land Use (MRLU) map and handbook coverage of Halifax County.

MRLU MAPPING FOR HALIFAX COUNTY

All map compilation work has been completed for Halifax County. The MRLU map set includes the NTS map sheets 11D/05, 11D/10 to 11D/16 inclusive, 11E/01, 11E/02 (and part of 11E/07), 11E/03, 21A/09 (and part of 21A/16). Mineral resource information provided on the Halifax County map set includes location data for sand and gravel resources, metallic minerals, industrial mineral, drillholes, pits,

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quarries and mines, mine tailings, gold mining camps, abandoned mine shafts, land forms including ice contact deposits, drumlins, eskers and sinkhole topography, and geological points of interest.

Land use classifications which prohibit or restrict mineral resource exploration and development have also been mapped. Protected lands in Halifax County include national parks, national historic parks, sites and Heritage canals, national defence lands, and NSDME closure lands. Limited use lands plotted on the MRLU maps include provincial parks and park reserves, major airports, water supply watersheds, preservation areas, game preserves and sanctuaries, wildlife management area, migratory bird sanctuaries and national wildlife areas, protected beaches, urban areas, indian reserves and designated ecological sites. Some protected lands are supported by law while other classifications are defended by their custodians or by public opinion.

A 1:500 000 scale map (NSDME OFM 86-31) of the Province, compiled earlier in the project, shows the location, size and distribution of protected and limited use lands in Nova Scotia. Copies of this map can be acquired from the NSDME Library in Halifax.

MRLU HANDBOOK FOR HALIFAX COUNTY

In addition to the MRLU map compilation for Halifax County is the development of a handbook containing elaborations on the plotted data. The MRLU Handbooks can be used as an extension to the master legend of the MRLU maps. The handbook for Halifax County is presently in draft form.

The MRLU Handbook and map set for Halifax County is the first to be done for the Province. Halifax County planners have been very helpful in these initial stages and are very

supportive of the project. Many of the initial project hurdles have been worked out with Halifax County which will help us in the mapping and text compilation for the other counties and move the project to swift completion.

QUESTIONNAIRE

The staff of the Land Use Planning project developed a questionnaire this year to survey the provincial and municipal planning community on the planning status, legislation regarding mineral extraction activities, mineral resource management and issues concerning mineral exploration and development of their region. A report discussing the results will be available in time for the 1987 Open House and Review of Activities.

AQUACULTURE

The NSDME along with 4 other provincial departments, participates in the aquaculture review process in accordance with section 9(3) of the Aquaculture Act.

Aquaculture has become a growth industry in Nova Scotia in the last few years and this year many application forms have been submitted for sites in the many sheltered coves along Nova Scotia's coastline. Resource sectors such as fisheries and mining must find ways of avoiding conflicting land use activity and adhering to proper resource and land use management. The review process for aquaculture licenses allows the Department to screen all proposed sites for potential conflict with the exploration and mining sector. This is in keeping with the necessity to monitor activities of all the resources sectors so as to maintain a relatively conflict-free land management practice.

The land use planning staff has the responsibility of reviewing aquaculture applications for the Department. All proposed sites are

plotted on Mineral Claims Reference Maps and identified with a licence number. When the applications have undergone individual reviews, the granted licenses will be identified on the maps by their designation dates.

MINERAL RESOURCES AND PLANNING

The Land Use Staff is also concerned with the increased interest the Land Use Project has created among the provincial and municipal planning community. The Department is now receiving requests from planners for geological and mineral resource information for their planning districts. In response, the Land Use planners have prepared and supplied

several reports and maps with current mineral resource information.

Without a provincial land use policy for mineral resource lands, planners are not obliged to consider geoscientific data in their background research in the planning process. Therefore, an aim of this project to ensure that municipal planners consider geoscientific data and include policy which protects known mineral, sand, gravel and rock deposits. Until a mineral land use policy is adopted, the land use staff of the NSDME will encourage community planners to use mineral resource information in the land use planning process.

AUTOMATION IN THE MINERAL DEVELOPMENT DIVISION¹

L. Crust

BACKGROUND TO AUTOMATION

During the spring of 1986 the Mineral Development Division of the Nova Scotia Department of Mines and Energy purchased 4 micro-computers for the Halifax office: 1 IBM XT as a word processing workstation, and 3 IBM ATs to be used by Mineral Rights, Mineral Inventory and Land Use Policy Development groups. WordPerfect was bought as the word processing software package, Lotus 123 as the spreadsheet package and dBASE III PLUS as the database management package.

In addition, Land Use Policy Development purchased the PMAP geographic information system software and the ATLAS-AMP mapping software, Mineral Inventory bought the Advanced Revelation database management software, and Mineral Rights hired a computer programmer to develop a customized database management application using dBASE III PLUS.

Most employees of the Halifax office of the Division have some experience on the computers, and planning and development has begun on 29 databases.

Since June 1987 the Regional Exploration Services group in Stellarton has borrowed a portable IBM PC from the Nova Scotia Department of Government Services, and used it for word processing (WordPerfect) and spreadsheet applications (Lotus 123). The purchased computers, when they arrive, will be used for a greater

number of applications; to date the plans include 10 databases.

PLANS FOR 1987-88

INDUSTRIAL MINERAL, LIBRARY AND REGIONAL EXPLORATION SERVICES WORKSTATIONS

During the 1987-88 fiscal year the plan is to purchase micro-computers for the Industrial Minerals group, the Library, and the Regional Exploration Services group.

The Industrial Minerals group is responsible for conducting resource evaluation and research programs in order to identify development opportunities and attract development. As such it is generating new data on a number of selected commodities, and improving the existing database on at least 30 other industrial mineral commodities. The need to automate this process is acute because of the volume of data being collected. Automation will improve the storage, analysis and retrieval of this information.

The Library has identified 9 manual processes that could be automated including cataloguing, inventory control, budgetary spending, acquisitions, circulation, serials, mailing list, interlibrary loans and on-line database and information searches. The creation of the cataloguing/indexing system has the highest priority for the 1987-88 fiscal year. Automation in the library will reduce or eliminate the most time-

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consuming and labour-intensive practices. This will allow the staff to achieve increased productivity and efficiency, and so provide better and more timely information services to library users.

The Regional Exploration Services group in Stellarton is responsible for a number of functions that require automation:

- . maintenance of the core library, geotechnical data and materials storage;
- . exploration monitoring;
- . conducting statistical surveys of exploration and development expenditures;
- . monitoring maps and publications inventory, distribution and sales, and;
- . maintaining field equipment storage and inventory.

During the current fiscal year, this group plans to receive an IBM XT and an IBM AT.

NETWORKING MICROCOMPUTERS

The plan also includes the linking of workstations in local area networks. Workstations in the Halifax office are to be networked this year, while those in Stellarton will be networked during the next fiscal year.

Expensive devices such as hard disk drives and letter quality printers can be shared on a local area network, and reduce the need for multiple purchases. Similarly, expensive software packages become more economical when bought in multi-user packages for use on networks. These procedures will allow the Division to economize on purchases and optimize the use of computer resources.

Equally as important, networking

will also allow the Division to access and share common data files. This will not only reduce or eliminate duplication of effort and data, but the sharing of data files will lead to the development of a divisional database. Several projects require information being developed by others within the Division, and networking will allow for integration of the various files into a single database that can be interrogated easily from any workstation. Suitable safeguards exist to protect information from unauthorized users, and levels of security will be established to control access to confidential information.

The Division is planning to use Novell's Advanced Netware/286 as the networking software, and Advanced Revelation as the database management software. Advanced Netware/286 is the industry standard for networking and includes several advanced features for:

- . managing and accessing data on the hard disk,
- . controlling peripheral devices such as printers,
- . simplifying use by people at workstations, and
- . maintaining security and controlling access to the system.

Advanced Revelation is a powerful fourth generation software package that will serve virtually all of the database management needs within the Division. It is programmable, relational and multi-user, and has variable length fields and records as well as multi-value (or repeating) fields. It also includes a powerful applications generator.

The ability of the Division to manage its information and to serve the public will be greatly enhanced when these systems are in place and operating.

MEGUMA GOLD STUDIES: SOME BASIC OBSERVATIONS¹

P. K. Smith and D. J. Kontak

Current underground exploration, development and mining in several Nova Scotia gold districts offer an excellent opportunity to study these Lower Paleozoic, turbidite-hosted deposits. This has allowed both government and industry personnel to gain a much better understanding of the controls on, and the distribution of, Au mineralization in the Meguma Group. These observations have allowed the development of new genetic models for Meguma type deposits which will greatly assist in the growth of the gold mining industry in Nova Scotia. This paper provides a summary of the essential points fundamental to exploration for turbidite-hosted Au deposits in the Meguma Group.

STRATIGRAPHY

Perhaps the most striking, though not surprising, feature of these deposits is the stratigraphic continuity of the host rocks and many of the auriferous quartz vein packages (i.e. > 1 km strike distance). Individual beds and some semi-concordant quartz vein packages have not only been traced continually along strike, but have also been intersected in drill core at depths near 1 km below surface. This not only allows for excellent geological correlation and predictability of auriferous zones, but also increases the strong probability of great depth continuity for the Meguma Group Au deposits.

On a deposit scale, individual beds or groups of beds may be used as marker

horizons, making geological correlation relatively simple. Marker horizons vary from district to district and may include (1) thick greywacke beds, (2) laminated calc-silicate beds, (3) green, black or grey slates, (4) siltstones and (5) locally, quartz veins themselves.

STRUCTURE

The great majority of Meguma Group Au deposits lie on steep to overturned fold limbs at varying distances from anticlinal fold hinges. Invariably each of the gold districts constitutes a series of en echelon lenses, slightly discordant to bedding and associated with significant shear zones. These shear zones are predominantly strike parallel (with respect to local stratigraphy), and have been regarded as postdating upright folding, regional metamorphism (ca. 410 Ma) and granitoid plutonism (ca. 370 Ma). The recognition, or lack thereof, of the variably developed shear fabric superimposed on these gold districts has caused considerable confusion regarding the relative age relationships of quartz veins and structural fabrics (see Fig. 1a). Thus, erroneous conclusions were reported for the relative age relationships of vein emplacement for some Meguma Group Au deposits by previous workers who believed that all quartz veins were formed prior to deformation of the host rocks (e.g. exhalative model).

¹Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

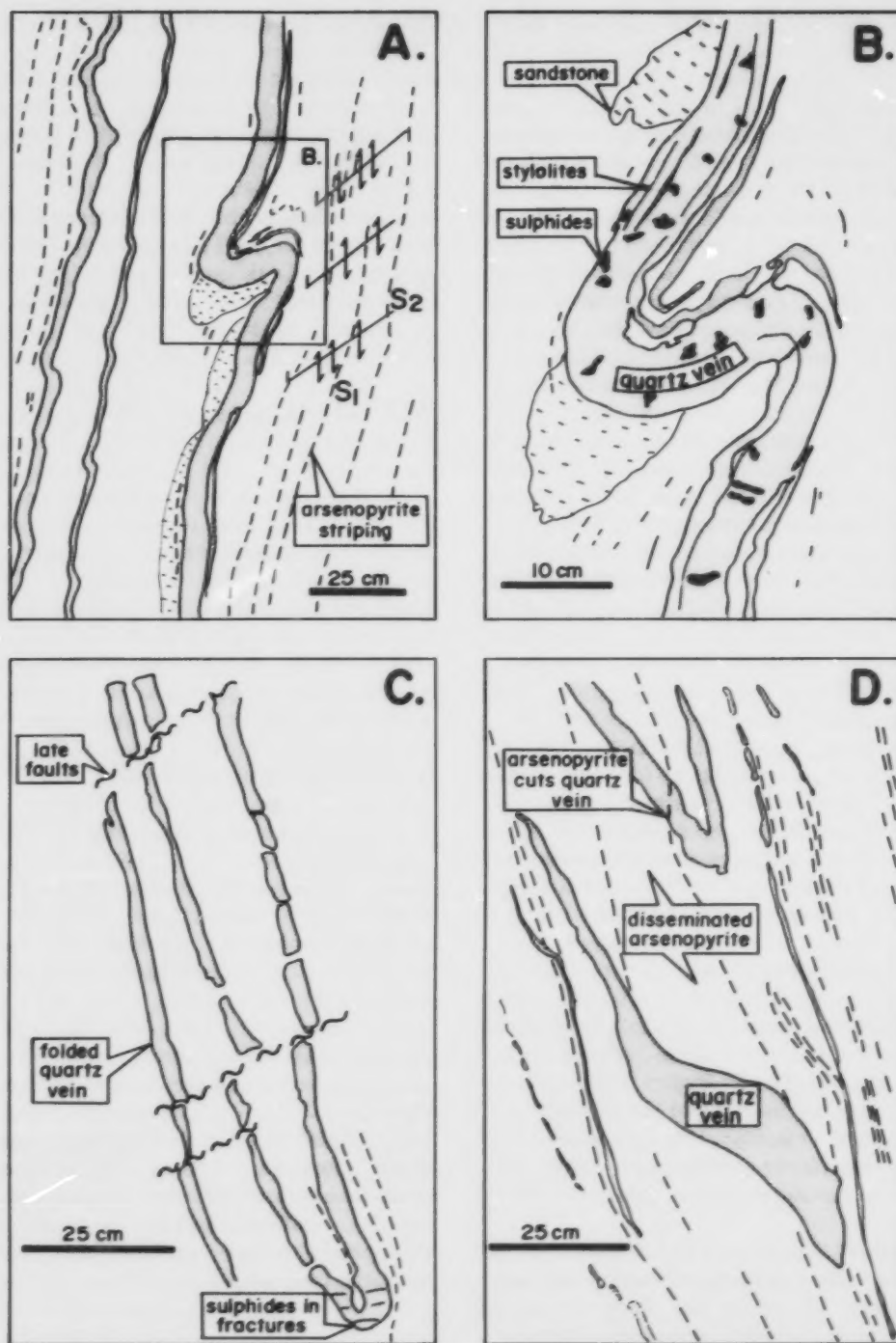


Figure 1. Sketches of underground exposures at the Beaver Dam Au deposit (a and b facing east, c and d facing west). In Fig. 1a, S_1 represents the regional penetrative fabric, whereas S_2 is a shear-related overprint fabric. Fig. 1c shows an intensely folded quartz vein and Fig. 1d illustrates sigmoidal tension veins representing early brittle conditions with a subsequent ductile overprint. Note the arsenopyrite striping which cuts the quartz vein in Fig. 1d, but which is partially rotated due to later deformation.

All observations suggest that quartz veins within the Au deposits were emplaced into a structurally active environment (Figs. 1a, b, c, d) that probably oscillated between ductile and brittle (e.g. contrast Figs. 1c and d), although ductile conditions dominated. The age of this emplacement is thought to be syn- to post-upright heterogeneous folding of the Meguma Group. Vein emplacement continued during regional metamorphism and plutonism. Strike and dip-slip shearing during and after major folding locally produced intensely deformed quartz veins (Fig. 1c). Subsequently, moderate to intense boudinage along extensional zones resulted in further structural deformation of quartz veins, pegmatites and host rocks.

ALTERATION

Pervasive alteration zones are common around the gold districts of Nova Scotia (Kontak and Smith, 1987; Smith and Kontak, 1987). They are characterized by ubiquitous and variably developed carbonate, sericite, sulphide, tourmaline and chlorite alteration which postdates the growth of metamorphic porphyroblasts and development of regional cleavage at the deposits. Silicification, which has been observed up to several km from known Au mineralization, is manifested by pervasive bleaching of all or part of specific greywacke beds to produce strata resembling orthoquartzites. Carbonate and sericite alteration are also widespread around the auriferous zones, whereas sulphide and chlorite alteration are restricted to specific strata. Locally, one or more alteration types may totally transform the physical and chemical character of specific rock types. Contacts of the alteration fronts are often very sharp and may either crosscut bedding at a high angle or parallel bedding surfaces. Alteration types are variably developed at different Au deposits, thus groups of auriferous zones characterized by the predominance

of one alteration type over the others may be produced. Mapping of the distribution of alteration zones has not yet been completed, therefore their geometrical relationship to auriferous horizons is unclear.

Many veins contain features suggesting a replacement origin for the quartz veins in contrast to open space infilling of dilational features. Perhaps some of the best evidence of this is represented by rooted wedges of wall rock which project into the vein (e.g. Figs. 2a, b), variably silicified wall rock fragments (Figs. 2c, d), and abundant stylolites representing the commonly referred to texture of crack-seal quartz (cf. Mawer, 1985, 1987; Figs. 2c, d).

QUARTZ VEINS

Quartz veins at all Meguma Group Au deposits examined may be classified by type based on their orientation, mineralogy and texture. However, extreme care must be exercised when attempting to establish relative age relationships between veins because many of them with differing mineralogy and orientation display intimate spatial relationships.

VEIN TYPES

Some of the most easily recognized vein types include the following:

- (1) semi-concordant: composite veins characterized by crack-seal and massive crystalline quartz textures (numerous sub-types; Figs. 2c, d);
- (2) fissure or bull (also pegmatoid): consist of coarsely crystalline quartz and are discordant to bedding;
- (3) angular discordant: characterized by tourmaline and (or) aluminosilicates;
- (4) replacement: end product of silicification (note that crack-seal

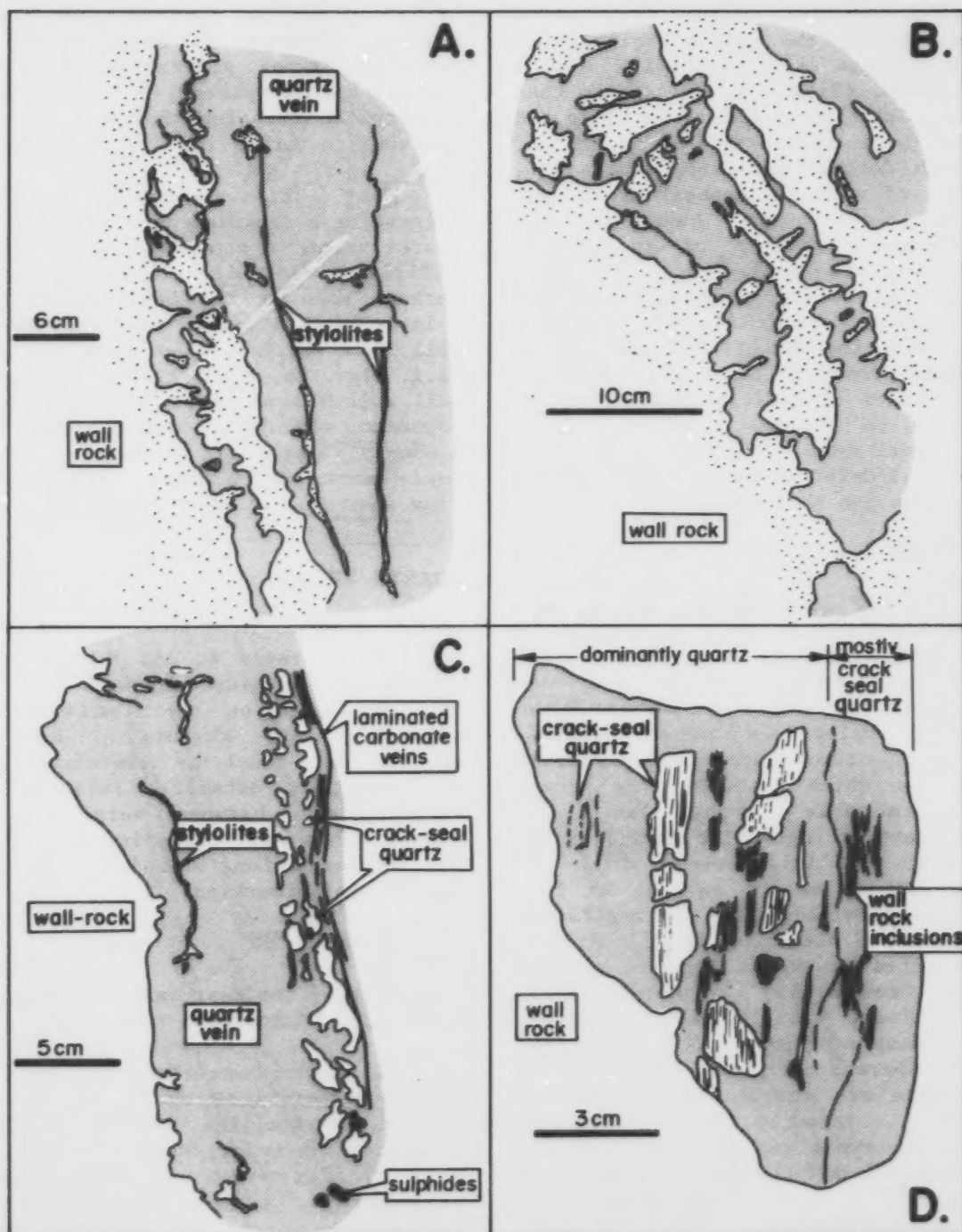


Figure 2. Sketches of quartz veins illustrating the development of replacement veins. Note the presence of rooted wall rock wedges penetrating the quartz veins in Figs. 2a and b, the zone of extensive crack-seal type quartz in Figs. 2c and d and the stylolitic textures in the veins. Figs. 2a, b and c are bedding parallel quartz veins (2c) and fissure or bull veins (2a, b) at the Beaver Dam deposit, while Figs 2d is the Marker Vein (hand sample) at the Tangier deposit.

veins may be a sub-type of this group; Figs. 2a, b, c, d);

(5) ac: upright veins perpendicular to the upright fold axial plane (ab plane);

(6) en echelon: essentially stratabound veins which locally form ladder type geometry depending on the degree of subsequent shear deformation. In conjunction with these dominant vein types are a host of other veins which display numerous orientations and crosscutting or interconnecting relationships at each deposit.

VEIN MINERALOGY

Both silicate and ore mineralogy within the quartz veins are extremely variable. Although quartz is the dominant silicate mineral in most veins, many other silicates are present, particularly at deposits hosted by rocks of higher metamorphic grades. Common vein mineralogy at most Meguma Group Au deposits includes plagioclase (of An₁₀₋₅₀ composition), Fe-rich chlorite, biotite, muscovite, calcite (Mn calcite, ankerite, ferroan dolomite), garnet, amphibole, andalusite, cordierite, tourmaline, scheelite, ilmenite, rutile and apatite. This assemblage strongly suggests that the chemistry of the ore-forming fluids was complex. Commonly one or more of these mineral phases occur in small to large clusters and may locally represent the dominant mineralogy of the vein. Such veins are referred to as 'pegmatoid' because of their obvious textural similarities to granitic pegmatites.

The common sulphide mineralogy associated with native Au in the quartz veins includes arsenopyrite, pyrite, pyrrhotite, chalcopyrite, galena, sphalerite and loellingite, with rare stibnite and molybdenite (?) occurring locally. Many of these minerals display variable textural and paragenetic relationships (e.g. there are several generations of arsenopyrite) as a result of both

primary differences in the sequence of crystallization and subsequent modification related to deformation.

Silicate and carbonate minerals display considerable local variation in concentration throughout quartz veins, especially where post-shear boudinage has been an important factor. Commonly boudin necks are characterized by new mineralogy comprising plagioclase and carbonate $\pm$ sulphides (commonly pyrite euhedra) and frequently devoid of quartz, while boudin lenses consist predominantly of strongly deformed and recrystallized quartz.

GOLD MINERALIZATION

Work to date on the Au deposits has demonstrated that native Au occurs in a number of specific sites, within both the quartz veins and the host rocks. Some of these sites, in order of volumetric importance, are as follow:

(1) native Au occurs primarily in semi-concordant veins; variable amounts of Au occur in all of the other vein types, but generally it is not volumetrically as important;

(2) native Au as inclusions in sulphides hosted by both veins and wall rocks;

(3) native Au in silicate minerals (other than quartz) in veins and host rocks. This occurrence is most common in the higher metamorphic grade deposits (e.g. Forest Hill, Cochrane Hill);

(4) native Au in altered siltstones and black shales having little or no obvious spatial association with quartz veins.

Auriferous quartz veins represent the dominant source of Au. However, excitement is being generated by analyses which reveal the presence of ore-grade concentrations of non-visible Au in slates and siltstones at several Meguma gold districts. The

significance of these analyses awaits further documentation, however it is evident that such findings could vastly increase the bulk recoverable ore potential of the Meguma-hosted Au deposits of southern Nova Scotia.

SUMMARY AND CONCLUSIONS

Present and continuing studies of Meguma Group Au deposits reveal new information which requires reassessment of our concepts of both the genesis of these deposits and their actual size and future potential. All indications suggest that mineralization is quite late with respect to deformation, metamorphism and the plutonic evolution of the Meguma Zone during the Acadian Orogeny. It appears that Au mineralization formed as an integral part of the tectonic evolution of this terrain in response to regional processes rather than perturbations in the local geology. These factors enhance the belief that the potential for Au deposits of significant size to be developed throughout the entire Meguma Group is indeed excellent. The recent delineation of considerable ore reserves in areas which had minimal historical production is a measure of the real potential of Meguma Group gold deposits. Only further work by industry will reveal the possible size of these deposits.

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THE METAMORPHIC AND STRUCTURAL EVOLUTION OF THE EASTERN MEGUMA TERRANE¹

S. L. Douma

INTRODUCTION

Gold mineralization in the turbidite-hosted metasedimentary rocks of the Lower Paleozoic Meguma Group occurs both in and adjacent to quartz veins of different character and ages (Campbell and Poole, 1862). Smith and Kontak (1986) concluded, after preliminary studies of 30 gold districts in the eastern portion of the Cambro-Ordovician Meguma Terrane, that several stages of vein formation span syn- to post-tectonic conditions. From their work it became evident that the variety of quartz veins, both textural and mineralogical, could simply not be accommodated by any one of the previously proposed models. In order to help understand the geological

development of these gold-associated veins a project was initiated for the eastern Meguma Terrane with the following goals: (1) to document the structural history, (2) to document the metamorphic fabrics (both contact and regional) developed during the deformational history, (3) to document the types of alteration associated with the auriferous zones and (4) to determine the relationships between Au mineralization and metamorphic and structural elements.

This summer's field work (Fig. 1) involved study of Meguma Group metasediments of chlorite and biotite regional metamorphic grade between Sheet Harbour and Halifax (NTS 1:50 000 maps 11D/10 to 11D/15) and biotite-

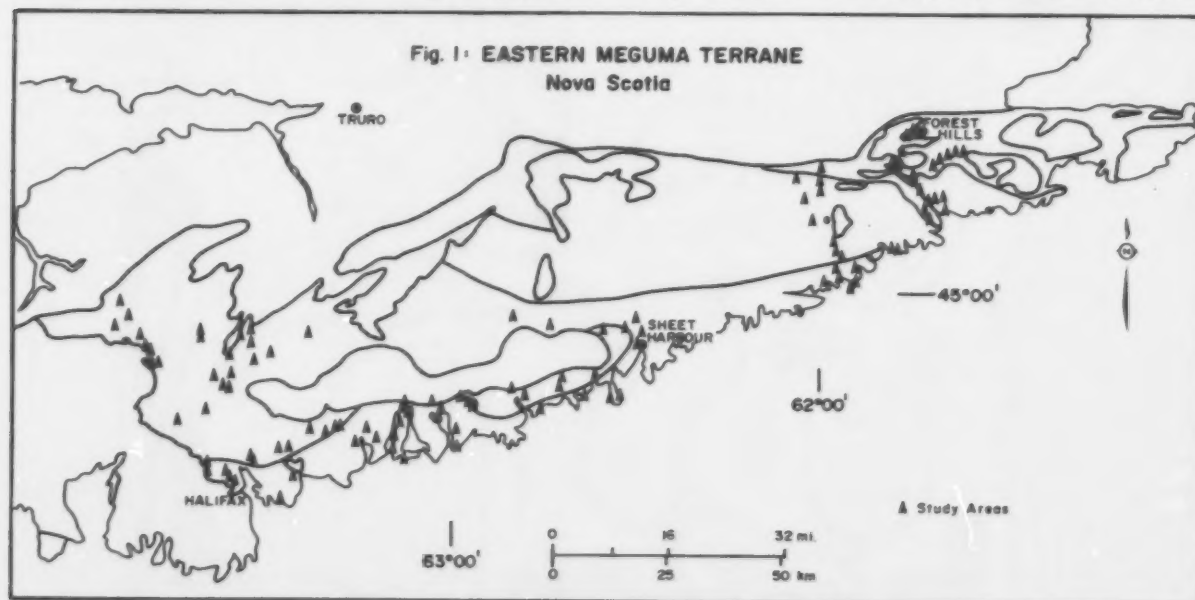


Figure 1. Location of study areas in the eastern Meguma Terrane.

¹Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement.

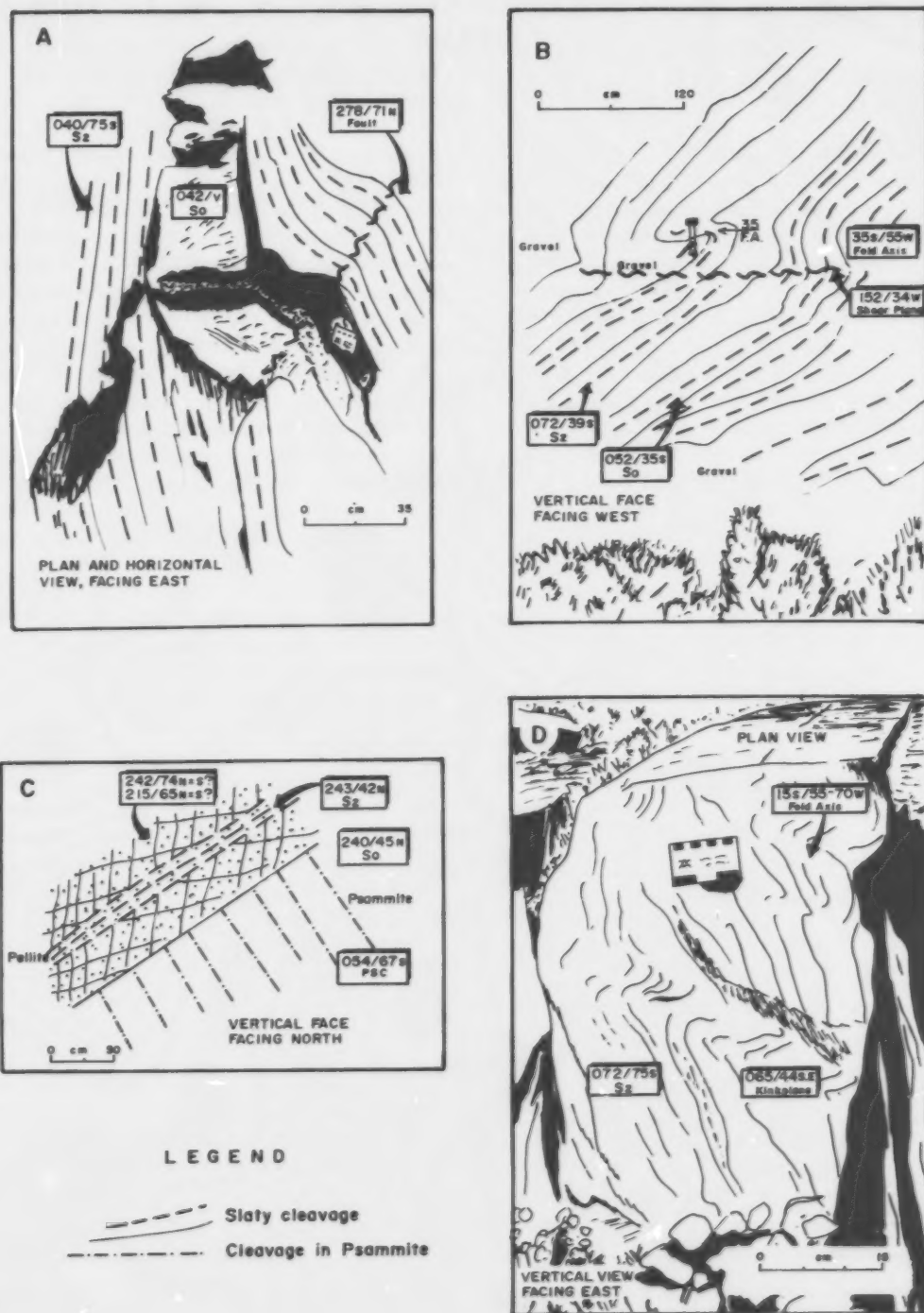


Figure 2. (a) Minor folding associated with fault movement. (b) Low angle, moderately open overturned folds. (c) Multiple slaty cleavage in pelitic horizons of the Meguma Group. (d) Kink bands.

garnet and andalusite-staurolite-sillimanite regional metamorphic grade between the Sherbrooke and Forest Hill gold districts (11E/1, 11E/8, 11F/4, 11F/5, 11C/13). The goal for this field season was to document regional and contact metamorphic facies in the eastern Meguma Group.

OBSERVATIONS

In the Meguma Group west of Sheet Harbour, the dominant structural features recorded are northeast-trending, upright, tight folds that plunge gently (0-20°) east and west (D₂: after Smith, 1983; Smith et al., 1985). Slaty axial planar cleavage and pressure solution cleavage in the more arenaceous strata are the predominant foliations associated with these major and minor (parasitic) folds. Late stage, northwest-trending faults superimpose a later brittle deformation on the Meguma Group rocks. Minor folds are occasionally associated with fault movement (e.g. Fall River, Figure 2a). In the area west of Sheet Harbour local deformation occurs, postdating D₂ deformation. This local deformation includes low angle, moderately open, overturned folds in the vicinity of Ashdale (Fig. 2b), multiple slaty cleavage nonparallel to S₂ axial planar cleavage 0.5 km west of Porters Lake on Highway 7 (Fig. 2c), and kink bands in the area between Lake Charlotte and Ship Harbour (Fig. 2d).

In the Sherbrooke and Country Harbour areas rocks preserving the five deformational phases recorded by O'Brien (1983), Keppie (1983), Smith (1983) and Smith et al. (1985) were sampled by Dr. G. Muecke in 1982 and 1983 and by the author this season. Petrographic descriptions of these samples are being prepared to determine the character of the metamorphic fabrics defining these deformational episodes.

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INVESTIGATION OF THE ARGENTIFEROUS BASE METAL POTENTIAL AT THE WALTON DEPOSIT, HANTS COUNTY¹

J. M. Patterson

The Lower Carboniferous, sediment-hosted Walton orebody was exploited between 1941 and 1978, during which time approximately 5 million tons of greater than 90% BaSO₄ were mined. The discovery in the late 1950s of



Figure 1. Composite level plan of the Walton deposit, Hants County.

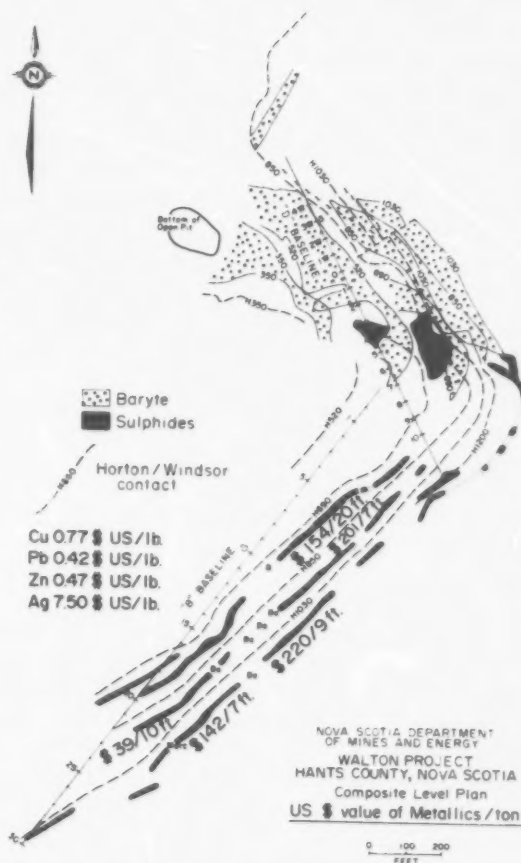


Figure 2. Composite level plan showing the value of metals per ton in US dollars.

argentiferous base metals associated with the barite led to the production of approximately 60,000 tons of concentrate grading 3.38% Cu, 28.11% Pb, 8.84% Zn and 62.62 oz Ag/ton.

¹Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

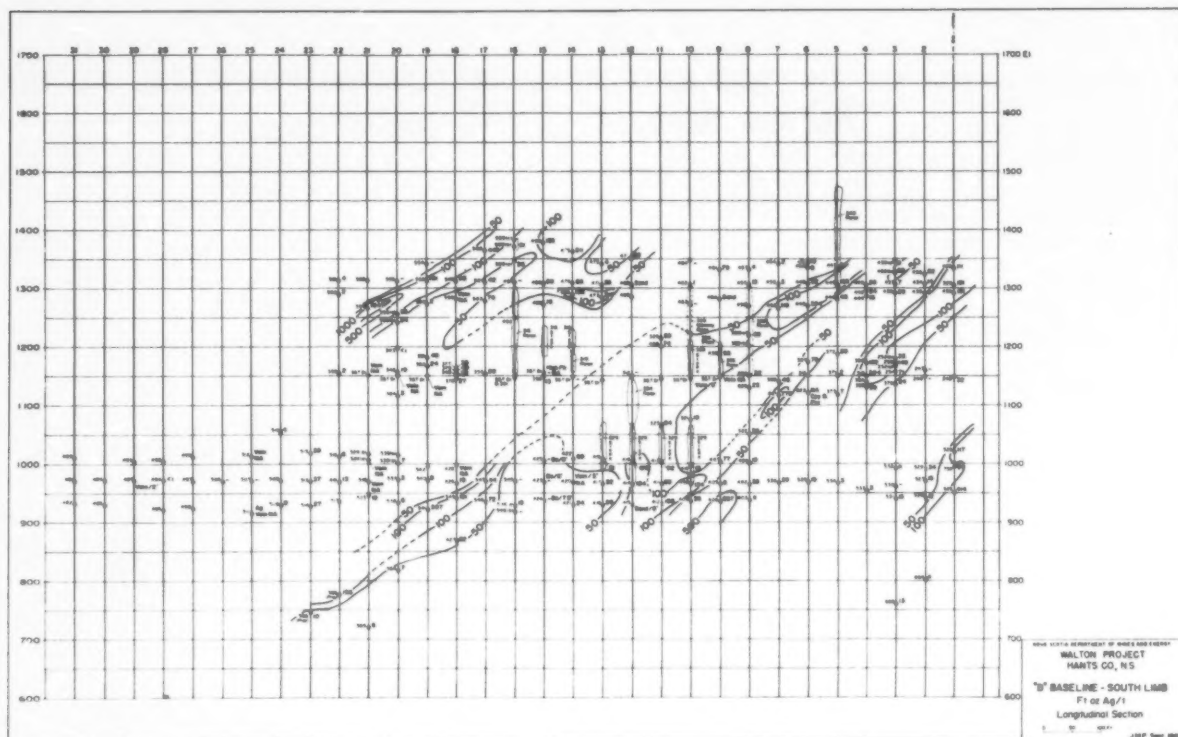


Figure 3. Longitudinal section along B baseline showing Ft oz Ag/t.

Approximately 400,000 tons of ore were milled at a head grade of 0.56% Cu, 4.33% Pb, 1.44% Zn and 10.9 oz Ag/ton. At current (September 1987) metal prices this translates into a value of \$140US per ton with Ag contributing approximately 60% of this value.

Investigation of the potential for additional argentiferous base metals in the deposit has identified two areas worthy of further study. Figure 1 is a composite level plan showing the barite and sulphide relationships down to the 1200 ft level. In the northern area (D baseline) an easterly plunge is indicated, the sulphides are tucked into the footwall of the barite deposit and mineralization is associated with a strong northwest-trending feature with associated faulting. Sulphides are present on the 1650 ft level in this area and the potential appears to be open to depth. The strike extent is limited here and the potential target, though of excellent grade and width (30 oz Ag per ton/29 ft), is not regarded

as the priority target. Of more immediate interest is the sulphide mineralization along the B baseline or South Limb where mineralization comprises argentiferous base metals with associated barite. Development and minor production have taken place primarily from three levels (690, 850 and 1030 ft levels) with only minor development on the 1200 ft level (Fig. 1). Three main correlatable pods of mineralization have been recognized and traced between the three levels, and grades increase with depth. Grades expressed in \$US per ton value of the total contained metals clearly demonstrate that economic values are present on the lowest levels in this area and, more importantly, the values increase with depth (Fig. 2). The updip potential is also of importance, as ore grade values are present above the 690 ft level.

Longitudinal sections (Fig. 3) showing metal values along this B

baseline illustrate the hypothesis of southwest-plunging 'shoots' or 'lodes' within the southeasterly-dipping mineralized sheet. The sections dem-

onstrate the up and down plunge potential in this B baseline area and indicate the optimum locations for future drilling programs.

ZINC ENRICHMENT AND EXPLORATION POSSIBILITIES AT YAVA MINE, SALMON RIVER, CAPE BRETON COUNTY¹

J. M. Patterson

During 1987 a follow-up drilling program was undertaken at the Yava Mine to further investigate the relative enrichment in zinc values indicated by assays of drill core from the 1986 drilling program (Patterson, 1987). Nine vertical holes, totalling 340 m, were drilled in the period 18 March to 12 May, 1987, in a program designed to more clearly delineate and extend the anomalous Zn area. Very pale, finely disseminated, interstitial sphalerite was encountered in sandstone. The best Zn intersection for disseminated sphalerite is 1.07% Zn over 1.9 m while the highest Zn value, 2.2% over 0.75 m,

is associated with pyritic sandstone containing coal debris.

Figure 1 shows the locations of the 1987 drillholes and displays the extent of the Zn-enriched area. It is apparent that the higher Zn values correspond with areas of lower Pb values. This further supports the hypothesis that a Zn orebody may exist down dip and at a higher stratigraphic level than the well documented Pb deposit.

Analogies have been drawn with the Laisvall sandstone-hosted Pb/Zn

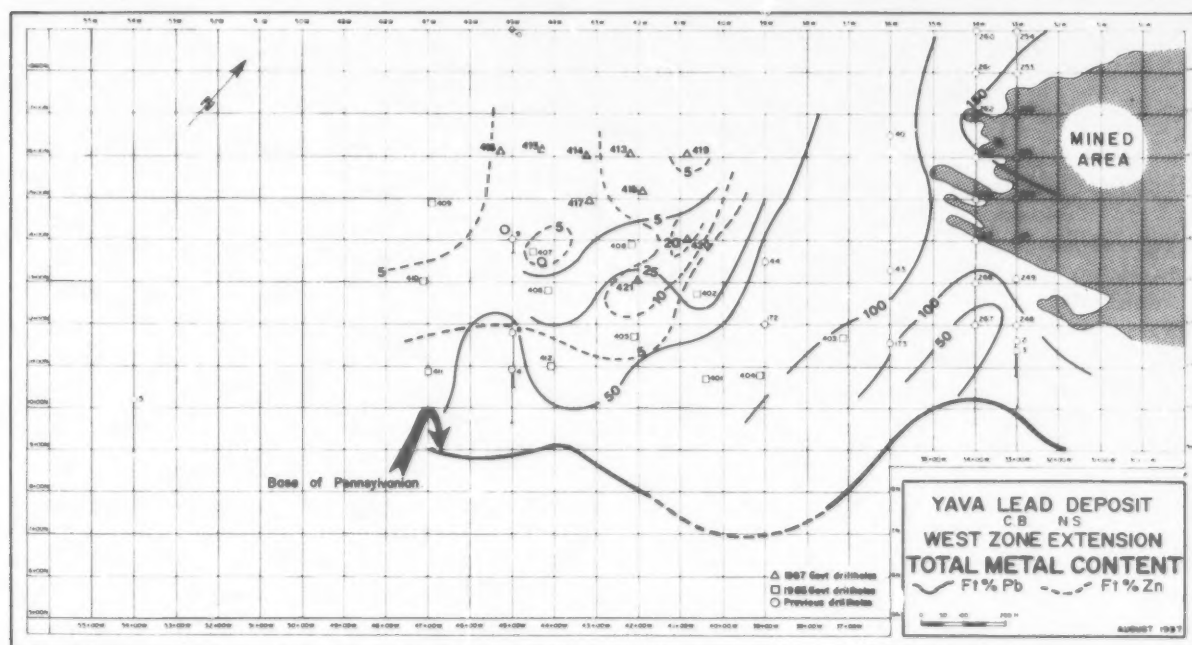


Figure 1. Total Pb and Zn contents of the west zone extension of the Yava lead deposit. Drillhole locations are also indicated.

¹Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

deposit in Sweden, where a large tonnage Pb deposit passes downdip to a Zn deposit which has no surface expression (Rickard, 1979). The results of this recent work require continuation of the investigation at the Yava base metal deposit.

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LOWER CRUSTAL XENOCRYSTS AND XENOLITHS IN THE TANGIER DYKE, EASTERN MEGUMA ZONE, NOVA SCOTIA¹

P. S. Giles and A. K. Chatterjee

INTRODUCTION

Mafic intrusive rocks which post-date Acadian (410 Ma) metamorphism cut Meguma Group rocks in the eastern Meguma Zone in two breccia pipes (Giles and Chatterjee, 1987) and in several NNW - trending dykes (Faribault, 1896; Jones, 1974; Henderson, 1986). The latter, of which the Tangier Dyke (Fig.

1) is the widest known, range in width from 2-15 m and are essentially vertical. The Tangier Dyke, like the Liscomb Complex breccia pipes (Giles and Chatterjee, 1987), contains extraordinary concentrations of exotic xenoliths. This dyke is completely exposed at five locations over a strike length of 1250 m and provides an excellent opportunity for investigation of these xenoliths, and consequently their implications with respect to the nature of crustal rocks beneath the Meguma Zone (Owen et al., personal communication). This brief report summarizes the results of this investigation to date. Detailed reports with complete documentation of results are in preparation.

THE TANGIER DYKE

The dyke is in sharp intrusive contact with metagreywacke of the Goldenville Formation (Meguma Group) of Cambro-Ordovician age, and cuts at a high angle across the northeasterly-trending Sober Island Syncline (Fig. 1). The outer margins of the dyke, symmetrical and similar at country rock contacts, comprise fine grained chilled zones (100 cm in width) containing vesicles filled with buff-coloured carbonate, quartz and epidote + chlorite. These chilled margins pass inward to intermediate zones (approximately 1.3 m in width) which are fine- to medium-grained and exhibit typical ophitic 'salt and pepper' textures. The dyke core (approximately 10 m in width) is characterized by

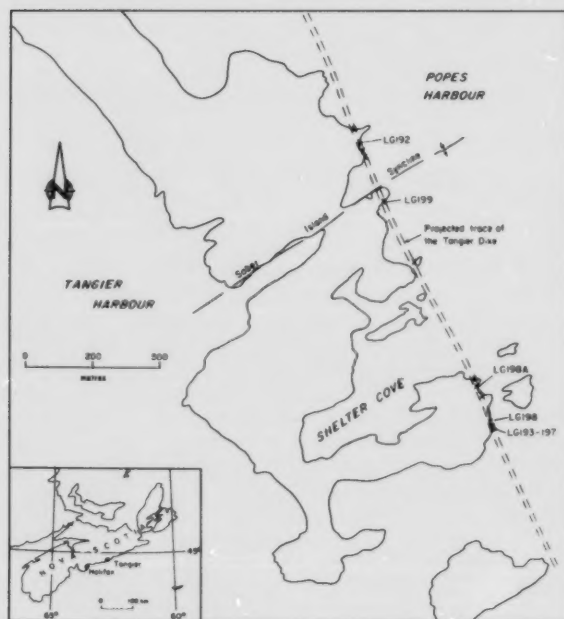


Figure 1. Location map indicating exposure and projected trace of the Tangier Dyke, eastern Meguma Zone of southern Nova Scotia. Country rock is entirely assigned to the Goldenville Formation, Meguma Group.

¹Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

abundant xenoliths which are variable in type and size.

Primary minerals in the groundmass of the Tangier Dyke form interlocking grains and include plagioclase (An_{47}), hornblende and biotite. Accessory minerals include magnetite, pyrrhotite, apatite and ilmenite. Strongly zoned plagioclase and hornblende are common as phenocrysts. Secondary minerals include sericite, epidote, calcite, chlorite and biotite.

Geochemically, the dyke matrix ranges from olivine normative basalt of calc-alkaline affinity (scheme of Irvine and Baragar, 1971) in the chilled margins to quartz, corundum and hypersthene normative chemistry in the intermediate and central zones. This variation in composition is related to both the degree and nature of contamination, described in subsequent paragraphs.

XENOCRYSTS

Relict minerals (xenocrysts) of quartz, K-feldspar, plagioclase II, clinopyroxene I and II, orthopyroxene I, II and III, Ti-rich calcic amphibole, kyanite, sillimanite, garnet I, II, III and IV, sapphirine I and II, Ti-rich zoned biotite II, rutile, corundum, spinel I, II and III, and sulphides, including pyrite, pyrrho-

tite, chalcopryrite and sphalerite, were noted in detailed petrographic study (Roman numerals indicate distinct compositional variants of the minerals). These xenocrysts, which may constitute up to 30% (volume) of some thin sections, occur both as individual phases or in some cases as inclusions in primary minerals (e.g. spinel, sapphirine, Cr-rich orthopyroxene in plagioclase). Where they occur as discrete grains, the xenocrysts are commonly mantled by either a dark brown glass of basaltic composition or a reaction rim. Mineral textures and compositions, determined by electron microprobe investigations, demonstrate that these xenocrysts could not have crystallized from the present host and that they formed under a high pressure regime.

XENOLITHS

Xenoliths in the central portion of the Tangier Dyke range from <1 cm to >1 m in diameter. Xenoliths of Meguma Group country rock are present, as are local small fragments of chilled margin. However, exotic xenoliths far outnumber these cognate and locally-derived inclusions. Exotic xenoliths are assigned to two populations based on the presence or absence of graphite.

Table 1 shows the variety of mineral assemblages in graphite-bearing

Table 1. Mineral assemblages in graphite-bearing xenoliths.

Sillimanite (I) bearing xenoliths	quartz-sapphirine-sillimanite sapphirine-orthopyroxene-garnet-sillimanite sapphirine-mesoperthite-sillimanite sapphirine-mesoperthite-orthopyroxene-spinel $\pm$ rutile-sillimanite $\pm$ biotite orthopyroxene-spinel-sillimanite $\pm$ biotite sapphirine-orthopyroxene-mesoperthite-sillimanite garnet-rutile-ilmenite-orthopyroxene-sillimanite
Kyanite and sillimanite bearing xenoliths; plagioclase common; lacks quartz-sapphirine-sillimanite assemblage; garnet grains typically surrounded by reaction rims; each assemblage contains kyanite and sillimanite (not listed).	quartz-plagioclase-orthopyroxene-garnet $\pm$ rutile $\pm$ mesoperthite plagioclase-orthopyroxene-garnet-biotite $\pm$ spinel quartz-plagioclase-garnet $\pm$ biotite $\pm$ mesoperthite sapphirine-spinel-corundum sapphirine-spinel-corundum-garnet-orthopyroxene
Quartz and feldspar rich xenoliths lacking sapphirine; kyanite and sillimanite (II) commonly present with the latter predominating.	quartz-K feldspar-plagioclase-garnet-orthopyroxene K feldspar-plagioclase-garnet-orthopyroxene-spinel $\pm$ corundum $\pm$ biotite plagioclase-garnet-orthopyroxene-spinel-rutile-ilmenite
Xenoliths devoid of aluminosilicates.	quartz-clinopyroxene-garnet-sphene $\pm$ apatite $\pm$ epidote $\pm$ rutile $\pm$ biotite quartz-clinopyroxene-plagioclase-sphene $\pm$ apatite $\pm$ biotite quartz-clinopyroxene-garnet-orthopyroxene $\pm$ apatite $\pm$ biotite quartz-clinopyroxene-orthopyroxene-plagioclase $\pm$ apatite $\pm$ biotite

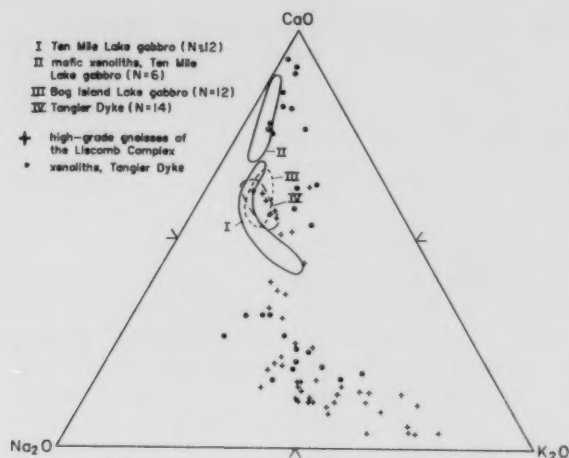


Figure 2. CaO - Na₂O - K₂O ternary diagram showing fields for mafic igneous rocks of the Tangier Dyke and mafic breccia pipes of the Liscomb Complex, with compositional ranges for high grade gneisses of the Liscomb Complex and the lower crustal xenoliths of the Tangier Dyke.

xenoliths. Note that Roman numerals indicate first and second generations of sillimanite.

Xenoliths devoid of graphite constitute the second broad category, which can be further subdivided based on the relative abundances of orthopyroxene, clinopyroxene and plagioclase. Other minerals present in trace amounts are biotite, amphiboles, chlorite, calcite, quartz, pyrite, magnetite and chalcopyrite. Subdivisions are as follow:

(1) xenoliths with orthopyroxene (opx) >> clinopyroxene (cpx), together constituting > 80% of the rock;

(2) xenoliths with cpx >> opx, otherwise similar to (1);

(3) xenoliths with cpx > opx, but together constituting <20% of the rock, which is dominated by plagioclase and dark brown hornblende.

Although several hundred thin sections of these xenoliths have been examined in the course of this study, they may not represent the total range in composition. However, these xenoliths clearly represent a heterogeneous protolith of mixed sedimentary and igneous parentage.

DISCUSSION

The exotic xenoliths of the Tangier Dyke are unlike any rock units exposed within the Meguma Zone, with the possible exception of high grade gneisses of the Liscomb Complex (Giles and Chatterjee, 1987; Fig. 2). Mineral assemblages and mineral chemistry of co-existing pairs reveal a high-pressure, high-temperature origin for the material, under conditions of granulite facies metamorphism. This same conclusion is reached, on the basis of mineral chemistry, for the widespread xenocrysts within the Tangier Dyke.

The xenoliths of the Tangier Dyke compare in several important aspects with granulites of the Grenville Province of the Canadian Shield. However, they also compare closely with Grenville-like rocks of similar age and metamorphic history from several other Precambrian terranes of the circum-Atlantic region. Moreover, the estimated pressure (12-14 kb) and temperature (> 1000°C) for probable peak metamorphic conditions in xenolith samples from the Tangier Dyke are unlike parameters recorded for regionally metamorphosed granulites (Lamb et al., 1986). Thus, a mantle-derived heat source for such extremes of temperature is suggested. The compositional range and depth of origin for exotic xenoliths in the Tangier Dyke point to derivation in the lower continental crust beneath the Meguma Zone of southern Nova Scotia. As such they represent, at least in part, the basement to the Meguma Group.

Links in space and time between mafic plutonism and granitoid emplacement in the Liscomb Complex suggests that the lower continental crust may be a significant factor in the understanding of Acadian metallogeny and plutonism in the Meguma Zone. Continuing investigations of these mafic rocks will emphasise possible links with precious metals and platinum group elements. On a more general note, exotic xenoliths incorporated within mafic bodies like the Tangier Dyke provide the first understanding of the lower crust beneath the Meguma Zone which may in turn have major implications for plate tectonic models of this part of the Canadian Appalachians.

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SOUTH MOUNTAIN BATHOLITH PROJECT: MINERAL DEPOSIT STUDIES, 1987¹

G. A. O'Reilly

SUMMARY

During the 1987 field season, studies of mineral deposits hosted by the South Mountain Batholith (SMB) concentrated on four locations (Fig. 1). Little information was available on three of these occurrences: the Sandwich Point greisen zone, the Timberlea - Roach Pond amethyst occurrences and the Bezanson Lake fluorite occurrence. The Upper New Cornwall Zn-As-Cu-Mo-Ag-Au prospect has been the focus of previous exploration activity (Corey, 1983) but only limited attention was given to determination of the deposit's genesis.

SANDWICH POINT GREISEN ZONE

Sandwich Point is located along the shore near the mouth of Halifax Harbour (Fig. 1). The area is underlain by a coarse grained, megacrystic, muscovite-biotite leucomonzogranite named the Halifax Peninsula Leucomonzogranite (MacDonald and Horne, 1986; MacDonald and Horne, 1987). Although not exposed, the contact of the leucomonzogranite with the Lower Paleozoic Meguma Group meta-sedimentary rocks lies a short distance offshore.

The leucomonzogranite has been intruded by a large sheeted quartz vein system, quartz vein stockworks and pegmatite. The zone is well exposed for 268 m along the shoreline but the true strike width is 122 m. The veins are usually greisen bordered and follow two

main orientations, 010° and 175°. A lack of crosscutting relations suggests both vein orientations and the pegmatite were all formed by the same hydrothermal event.

Mineralization at Sandwich Point consists of arsenopyrite and pyrite confined to the quartz veins and their immediately adjacent greisen selvages. The sulphide minerals occur both as fine grained masses and as large subhedral crystals. MacDonald and Horne (1986) reported that a sample from an arsenopyrite-rich quartz vein from this zone contained 7.6% As and 525 ppb Au.

This past field season the zone was plane table mapped at a scale of 1 inch=40 feet. Samples of sulphide-rich quartz veins from various parts of the section have been submitted for assay to assess their Au potential. A number of samples from the various alteration zones have also been submitted for major and trace element geochemistry to define the geochemical signature of the quartz-greisen system.

TIMBERLEA - ROACH POND AMETHYST OCCURRENCES

At Timberlea and Roach Pond, Halifax County, interesting quartz breccia veins and associated silicified zones occur within the coarse grained, megacrystic Halifax Peninsula Leucomonzogranite (Fig. 1; MacDonald and Horne, 1987). The zones

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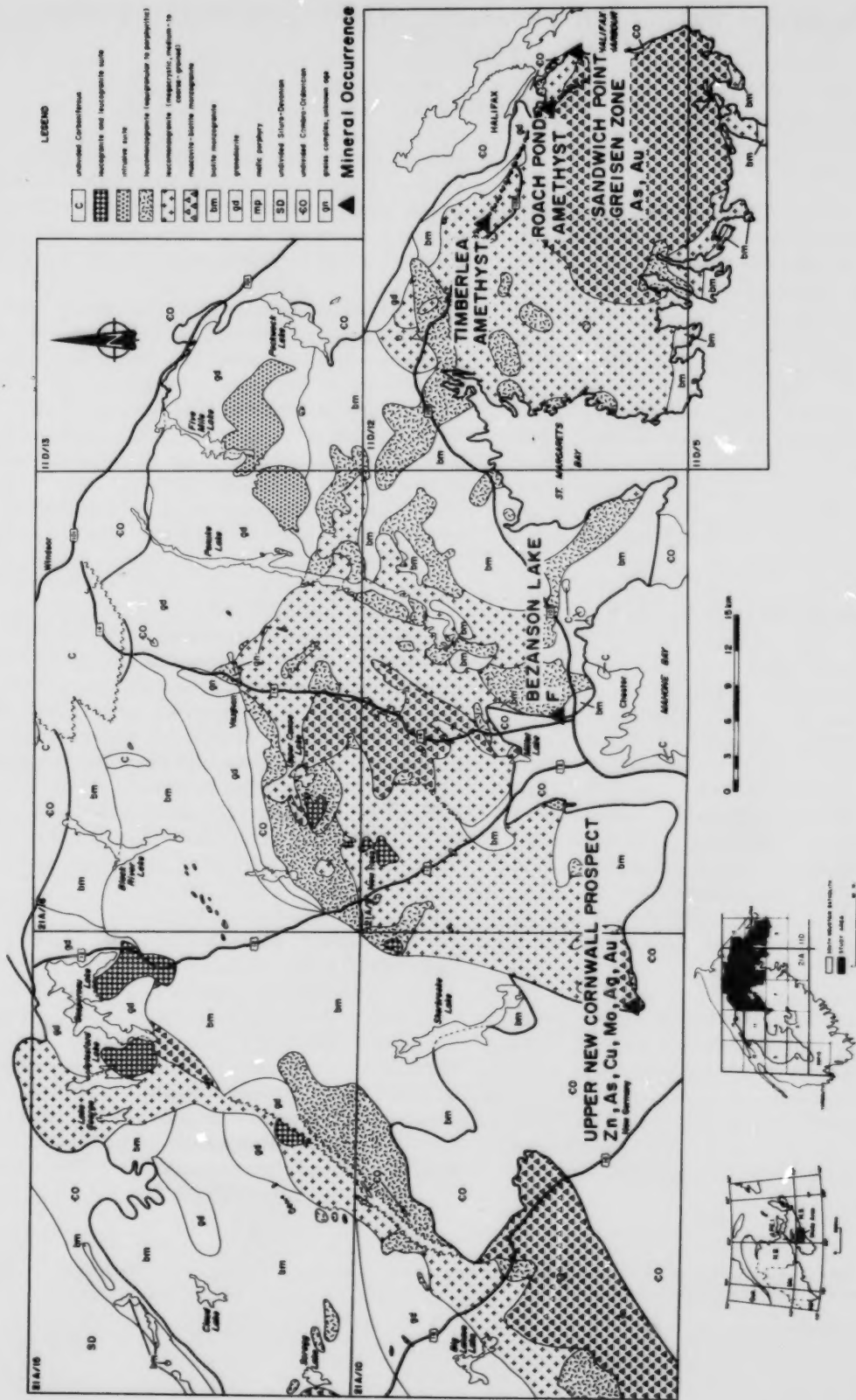


Figure 1. Locations of mineral deposits in the South Mountain Batholith studied in 1987.

have formed along a pronounced southeast-trending fault system extending from Timberlea in the northwest to Sheehan Cove in the southeast.

The Timberlea occurrence consists of veins of blocky, euhedral quartz (locally amethyst) up to 0.3 m wide enclosed in a zone of intensely silicified rock approximately 6.1 m wide. The zone is exposed on the north side of the railway line where the stream from Six Mile Lake enters Governor Brook. The silicified rock is partly silicified fault gouge but is predominantly either replaced monzogranite or silica introduced as open-space filling. The silicified rock varies in colour from white-grey, with darker examples containing finely disseminated pyrite.

At Roach Pond a similar zone of amethyst veins occurs in highly siliceous rock. This location has been covered by recent excavation except for one small outcrop, but considerable material exists as angular rubble distributed for about 91 m along the roadside. These rocks are similar to those at the Timberlea showing but at Roach Pond the fine grained siliceous rock has a higher sulphide content.

The Timberlea showing has been plane tabled at 1 inch=20 feet and traverses have been made to determine the strike extension of the silicified zone. Samples from both the Timberlea and Roach Pond occurrences have been submitted for assay to assess their Au potential.

BEZANSON LAKE FLUORITE OCCURRENCE

An interesting fluorite- and pyrite-bearing, hydrothermally altered and brecciated zone occurs at the contact of the New Ross Leucomonzogranite (MacDonald et al., 1987) with Lower Paleozoic Meguma Group metasedimentary rocks (Fig. 1). The

showing is best exposed at the southeast end of the open pit operated by South Shore Sand and Gravel Ltd. The contact is marked by significant slickensiding and brecciation, indicative of faulting. Alteration is not solely confined to the faulted rock as sericitization and greisenization effects extend several metres into both granite and metasediments.

Mineralization consists of fracture fillings of fluorite and cubes of pyrite in hydrothermally altered zones. An abundance of similar highly greisenized and silicified boulders of metasediment and granite occur over much of this area of the Batholith (approximately 25 km²). This strongly suggests the alteration effects seen in outcrop at the pit are widespread in this area and that an excellent potential for granophile element mineralization exists.

UPPER NEW CORNWALL PROSPECT

The Upper New Cornwall Zn-As-Cu-Mo-Ag-Au prospect comprises a collection of mineral occurrences located along the contact of the South Mountain Batholith with Meguma Group metasedimentary rocks. The occurrences are found west of the Blockhouse - Barss Corner highway at Upper New Cornwall, Lunenburg County (Fig. 1). First interest in the area was directed by Shell Canada Resources Limited when till geochemistry outlined areas of anomalous Sn and W (Wilson, 1978). Kidd Creek Mines Limited carried out geological, geochemical and geophysical surveys and discovered numerous boulders and several bedrock showings of highly greisenized and albitized rocks containing As, Zn, Cu and Mo sulphides (Corey, 1983).

The area is predominantly underlain by a megacrystic, muscovite-biotite monzogranite named the Whale

Lake Monzogranite (MacDonald et al., 1987). A small intrusion of fine- to medium-grained syenogranite intrudes the Whale Lake Monzogranite north of Otter Lake and some of the occurrences are related, at least spatially, to this intrusion.

Hydrothermally altered rocks in the area consist of a series of highly greisenized and albitized zones and quartz veins of a consistent 140° orientation. The muscovite-quartz greisen zones occur as borders to the quartz veins and as separate, highly greisenized fractures. Albitite and albitized monzogranite occur associated with the greisenized fractures. Both the greisenized and albitized rocks are haloed by sericitized monzogranite.

Mineralization, in order of abundance, consists of arsenopyrite, pyrite, sphalerite, chalcopyrite, covellite and molybdenite (Corey, 1983). Sulphides are concentrated within the quartz veins and greisens although significant arsenopyrite and pyrite are found within the albitized rocks. In addition, significant assay values of Au (970 ppb), Ag (11 ppm), Sn (200 ppm) and W (310 ppm) have been reported (Corey, 1983).

Samples of the various host rocks and alteration facies have been submitted for major and trace element geochemistry. The geochemistry is intended to allow comparison of the style of alteration of these occurrences with other deposits of Sn-W and related elements within the Batholith and further document the Au potential of this area.

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DEEP DIAMOND-DRILLING OF THE CALEDONIA GRAVITY LOW, QUEENS COUNTY¹

G. A. O'Reilly

Tin- and tungsten-bearing boulders were discovered in an area south of Caledonia, Queens County, by Shell Canada Resources Limited in late 1977 (Fig. 1; MacGillivray, 1983). Follow-up prospecting and till geochemistry resulted in discovery of Sn-W mineralization occurring in the following styles: (1) cassiterite and scheelite

in quartz veins and a granite breccia dyke complex and (2) scheelite, cassiterite and polymetallic sulphides in skarnoid layers within Meguma Group metasediments (MacGillivray, 1982).

The follow-up mapping also outlined contact metamorphic and hydrothermal effects within the Meguma

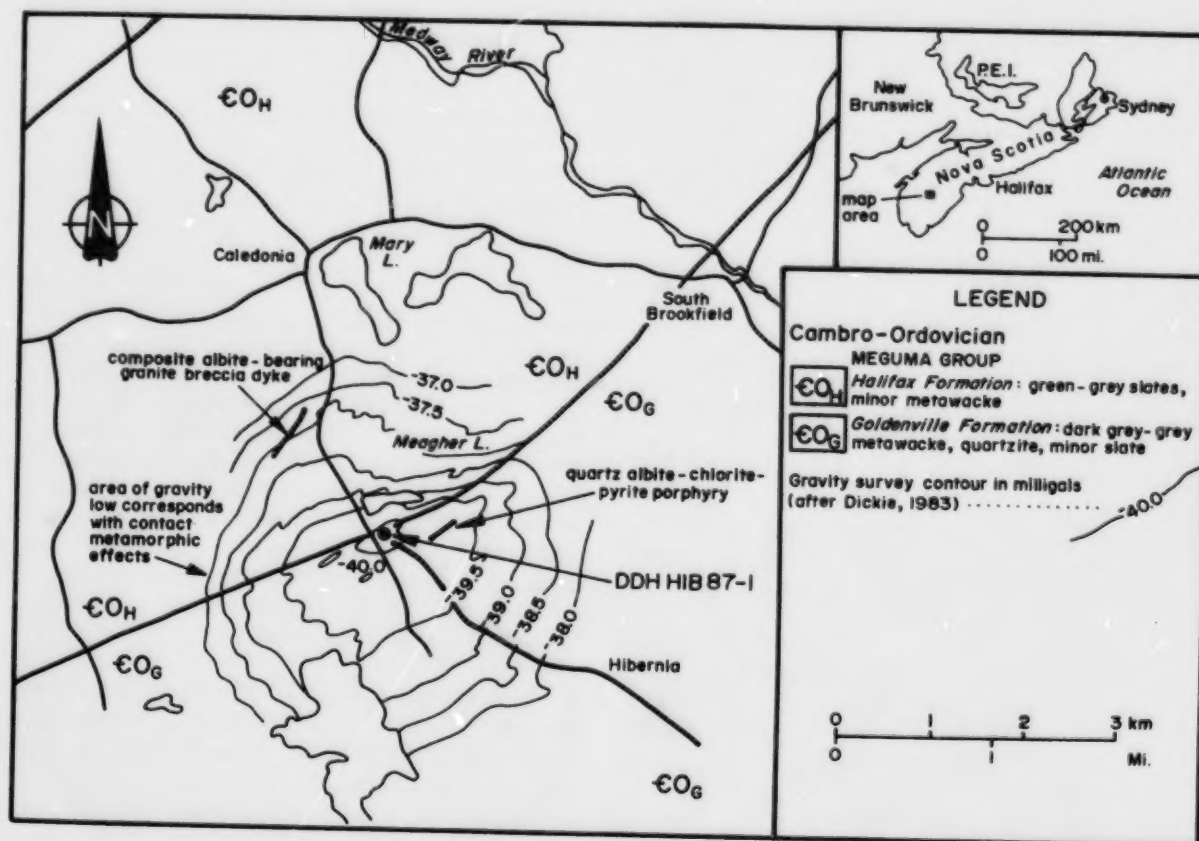


Figure 1. Geology map of the Caledonia - Hibernia area, Queens County, showing the location of DDH HIB87-1. Gravity survey results from Dickie (1983). Locations of breccia and porphyry dykes are also plotted.

¹Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

Group metasediments in this area. A gravity survey was carried out and outlined a circular gravity low underlying the area hosting the mineral occurrences and contact metamorphic effects (Fig. 1). It was concluded that the gravity low probably represented a buried specialized granite cupola from which the granite breccia complex is an offshoot and that the hydrothermal fluids and mineralization are associated with the cupola (MacGillivray, 1982; O'Reilly, 1985). Specialized granite cupolas are often loci of significant granophile element mineralization (Stemprok, 1979). However, two diamond-drill holes (197 m and 236 m) failed to intersect the hypothetical cupola (MacGillivray, 1983). Billiton Canada acquired the ground in late 1982 and carried out a more detailed gravity survey (Dickie, 1983).

The Nova Scotia Department of Mines and Energy, using the data from previous explorations, undertook a diamond-drilling project in order to further study the gravity low. The main purposes of the project were to:

- Provide a complete section of the exo- and endo-contact zones of a specialized granitic cupola for detailed geological and geochemical study.
- Evaluate the use of gravity surveys in locating buried or near surface granite cupolas in the Meguma Zone.

SUMMARY

Drilling of a vertical diamond-drill hole commenced in May 1987 at a site along the Caledonia-Hibernia road a short distance south of Meagher Lake (Fig. 1). This area occupies the center of the bulls-eye shaped gravity low and therefore likely represents the point at which any buried cupola would

be closest to the surface. Drilling continued until late August when the hole was terminated at a depth of 681 m.

To date the core has been logged in detail and petrography is being carried out. Samples representative of the skarnoids, hydrothermally altered bleached zones and unaltered wackes have been submitted for major and trace element geochemistry.

Although granite was not intersected, a number of features were recognized in the metasedimentary rocks which suggest this area is underlain by a granitic source. If so the cupola occurs either at a deeper level or adjacent to the selected site.

The drill core section consists predominantly of fine- to medium-grained metawacke and quartzite of the upper Goldenville Formation (Fig. 1). In general, the units vary in colour from dark to medium grey. In the upper portion of the hole light green semipelite and pelite layers are spotted with cordierite and (or) chlorite porphyroblasts. Downward in the drill section, the size of the porphyroblasts increases, indicating progressive development of cordierite. If cordierite development is due to contact metamorphism then the granitic source is being approached near the bottom of the drillhole.

Throughout the drill sequence, zoned, well developed, bedding-concordant skarnoid layers occur and are of particular interest as they often contain a significant amount of scheelite. Skarn mineralized with Sn, W, Cu, Pb and Zn was reported in this area by MacGillivray (1983).

The skarnoid layers range in size from a few cm to 1 m thick but most average 20-30 cm. The skarnoids represent extensively metasomatized units, as shown by their mineralogy, diffuse alteration haloes and zonal

structure. Their size, general cigar-shape to tabular form and calcareous matrix suggest they developed from either carbonaceous concretions or calcareous beds within the Goldenville Formation.

Similar units occur throughout the Goldenville Formation elsewhere in the Meguma Zone (Purves, 1974; Cullen, 1983). In those areas the skarnoids, or calc-silicates, form zoned, extensively metasomatized units, but elevated levels of Sn and W are known only in close proximity to granitic plutons.

At various intervals throughout the sequence extensive fracture controlled bleaching and (or) silicification of the Goldenville Formation has developed. The bleached zones range from less than a centimetre up to 12 m thick and occur within units rich in skarnoids and brecciated metawacke zones.

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SOUTH MOUNTAIN BATHOLITH PROJECT: PROGRESS REPORT¹

M. A. MacDonald, M. C. Corey, L. J. Ham and R. J. Horne

INTRODUCTION

Geological mapping of more than half of the South Mountain Batholith (SMB) was completed during the 1985 and 1986 field seasons (Fig. 1). The current year has been used to:

- . prepare a series of 1:50 000 geological maps for the eastern SMB,
- . assess the mapping done so far and evaluate the classification scheme for subdivision of the granitic rocks,
- . begin writing a final report for the project and
- . prepare for the mapping of the remainder of the SMB.

In addition to these activities, research into several related topics has been conducted during the past year. Summaries of this research are presented in this paper and the next four papers in this volume. Topics which have been addressed in this volume include the evaluation of structural data (i.e. orientation of quartz veins, aplite/pegmatite dykes, joints and megacryst alignments) collected throughout the Batholith (Horne et al., 1987); the modes of occurrence and composition of muscovite in the Batholith (Ham, 1987); the assessment of published airborne radiometric data from the Geological Survey of Canada in light of recent mapping (Corey, 1987); and various aspects of zoning in the Halifax Pluton (MacDonald and Horne, 1987).

GENERAL GEOLOGY

The classification scheme for subdivision of the granitoid rocks of the eastern SMB into distinct mappable phases is based on texture (e.g. equigranular, porphyritic, megacrystic, seriate), grain size (fine= <0.1cm, medium= 0.1-0.5cm, coarse= >0.5cm) and visual estimates of the modal percentages of biotite, muscovite, cordierite and feldspar megacrysts (mostly alkali feldspar with minor plagioclase). Modal percentages of quartz, alkali feldspar and plagioclase, established from point counting of stained slabs, were used to determine lithologic type according to the classification scheme of Streckeisen (1976).

The above criteria allow subdivision of the SMB into eight rock types as follow: (1) mafic porphyry, (2) granodiorite, (3) biotite monzogranite, (4) muscovite-biotite monzogranite, (5) leucomonzogranite which is subdivided into (a) medium- to coarse-grained, megacrystic leucomonzogranite and (b) fine- to medium-grained leucomonzogranite, (6) intrusive suites and (7) leucogranite and leucogranite suites. The distribution of these rock types in the eastern SMB is displayed in Figure 1. Detailed descriptions of individual map units from the various map sheets are presented in MacDonald and Horne (1986), Corey (1986), Ham and Horne (1986) and MacDonald et al. (1987).

¹Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

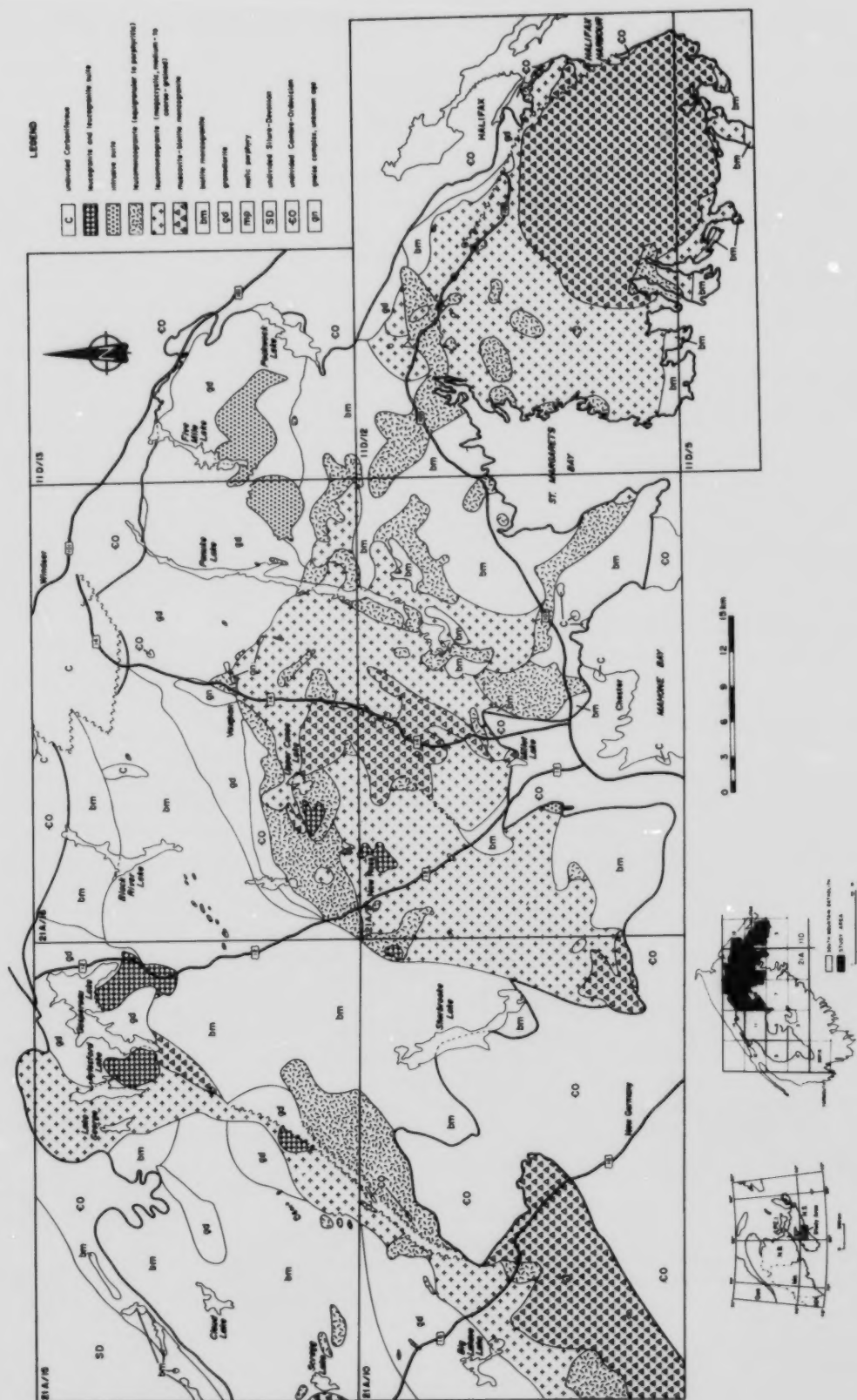


Figure 1. Geological map of the eastern South Mountain Batholith.

The following is a general description of the eight rock types in the SMB.

(1) **Mafic Porphyry:** The term mafic porphyry has been applied to a distinct group of rocks which: (i) are generally fine- to medium-grained, (ii) are porphyritic with phenocrysts of quartz, K-feldspar and plagioclase, and (iii) contain an anomalously high percentage of biotite (15-20%). Mafic porphyry commonly contains small (average 10 cm) xenoliths, some of which contain >90% biotite. Volumetrically, mafic porphyry constitutes a small portion of the SMB, generally covering only a few square kilometres or less, and most often occurs as xenoliths within other phases.

(2) **Granodiorite:** Rocks designated as granodiorite most often plot in the granodiorite field of the Streckeisen classification scheme, although some rocks of monzogranitic composition may be present. Granodiorite is usually medium- to coarse-grained with a megacrystic texture, although some medium grained seriate rocks occur near the granite/country rock contact. Biotite content ranges between 12-20% whereas muscovite is present in only trace amounts. Xenoliths are common to abundant in this unit, constituting up to 1% of the rock volume.

(3) **Biotite Monzogranite:** Rocks of this category closely resemble granodiorite, however staining of samples indicates a predominantly monzogranitic composition with only minor granodiorite. Biotite monzogranite is generally light- to dark-grey, medium- to coarse-grained and slightly to moderately megacrystic (2-15%). Biotite constitutes 10-18% of this rock type whereas muscovite and cordierite are present only in trace amounts. Xenoliths are common, but generally are not as abundant as in the granodiorite.

(4) **Muscovite - Biotite Monzogranite:** Rocks of this group may visually resemble the granodiorite and biotite monzogranite. However, this unit is characterized by lower biotite content (7-10%), minor muscovite (0.5-2%) and generally trace amounts of cordierite, although cordierite may constitute 1-4% locally. These rocks plot consistently in the monzogranite field of the quartz-alkali feldspar-plagioclase (QAP) diagram. Muscovite-biotite monzogranite varies from fine- to coarse-grained (usually medium- to coarse-grained) and may contain 2-20% megacrysts. Xenoliths are common but not abundant.

(5) **Leucomonzogranite:** This category is subdivided into two groups:

(a) medium- to coarse-grained, megacrystic (15-50%) rocks which are whitish-grey to buff, pink or orange. Some areas are only slightly megacrystic (5-10%). They contain 4-7% biotite, 1-4% muscovite, variable amounts of cordierite (trace- 4%) and plot near the syenogranite/monzogranite boundary of the QAP diagram. Xenoliths are very rare. Slight to moderate pervasive hematization and saussuritization of plagioclase is characteristic of this unit.

(b) fine- to medium-grained rocks which may be equigranular, aplitic or porphyritic in texture. Colour ranges from light grey to buff, pink and orange. Biotite content ranges from 2-7%, muscovite constitutes trace-5% of the mode whereas cordierite is present only in trace amounts. Slight to moderate pervasive hematization and saussuritization are characteristic of this phase. Xenoliths are rare.

(6) **Intrusive Suites:** Intrusive suites are predominantly monzogranitic in composition, although minor syenogranite and leucogranite (i.e. <2% total mafic minerals) are often present. Rocks of this group are distinguished by extremely variable textures (e.g. equigranular, aplitic (saccharoidal), pegmatitic, seriate,

porphyritic and megacrystic) which display complex contact relationships. Several textural and compositional varieties may be observed within a local area and often within the same outcrop. Grain sizes range from fine to coarse and mineral constituents include quartz, alkali feldspar, plagioclase, muscovite, biotite, cordierite and andalusite and other accessories. Xenoliths are rare.

(7) Leucogranite and Leucogranite Suites: These rocks plot predominantly in the monzogranite field of Streckeisen, although minor syenogranite is also present. Rocks are generally fine- to medium-grained. The distinguishing feature of this phase is the low content of mafic minerals (<2% biotite and cordierite) and the elevated content of muscovite (2-10%) compared to all other rock types. Textures are similar to those of the fine- to medium-grained leucomonzogranite and intrusive suites. These rocks are termed leucogranite suites where textures are extremely variable within local areas or in individual outcrops.

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A RE-INTERPRETATION OF U-TH RATIOS IN THE NEW ROSS AREA: EVIDENCE FOR A ZONED PLUTON¹

M. C. Corey

The presence of a zoned pluton in the New Ross area has been indicated by recent bedrock mapping (Ham and Horne, 1986; MacDonald et al., 1987) and is corroborated by a re-interpretation of existing airborne radiometric data. The use of airborne radiometric surveys as an indicator of granophile element specialization, and hence increased differentiation within a cogenetic suite, has been documented by several authors (e.g. Chatterjee and Muecke, 1982; Ford and O'Reilly, 1985). They concluded that variations in U and Th concentrations, specifically the U/Th ratios, are useful in defining areas of specialization and possibly mineralization within the granitic rocks of the South Mountain Batholith.

The New Ross Pluton (NRP) comprises:

(1) an outer rim of medium- to coarse-grained, texturally variable biotite - muscovite leucomonzogranite which in turn contains numerous small, finer grained, texturally variable bodies of leucomonzogranite, leucogranite and syenogranite. These latter rocks in particular display variable degrees of both fracture-related and pervasive metasomatic-hydrothermal alteration.

(2) a core of a fine- to coarse-grained, predominantly seriate textured muscovite - biotite monzogranite.

Geochemically, the rocks of the NRP show a trend of progressive U increase and Th decrease from the core to the margin (Fig. 1). The smooth

trend and limited scatter in the highly evolved rocks displayed in the Th/U v.s. Zr/U plot (Fig. 2) suggests that U, Th and Zr were concentrated in the mineral phases. U and Th may have been remobilized in the greisens and other highly evolved rocks. However, there is no apparent enrichment in either element. This is characteristic of a differentiating cogenetic suite (Chatterjee and Muecke, 1982) and indicates a reverse zonation within the NRP. MacDonald and Horne (1987) report a similar zonation within the Halifax Pluton.

The geology map with radiometric contours (eU/eTh) (Fig. 3) for the New Ross area is based on existing 1 km

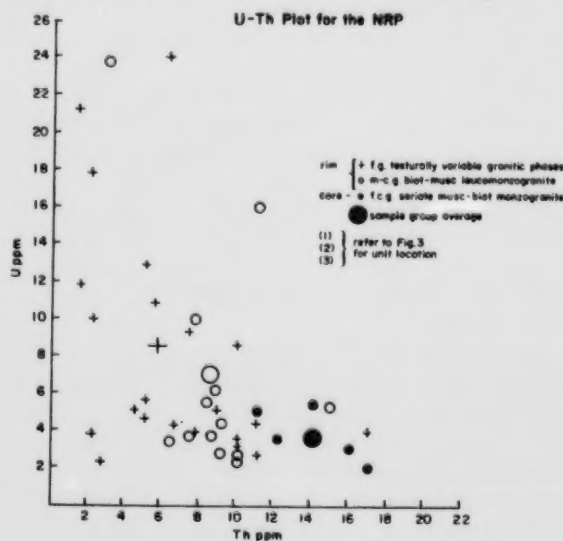


Figure 1. U-Th plot for the New Ross Pluton.

¹Funded by Nova Scotia Department of Mines and Energy under the Canada-Nova Scotia Mineral Development Agreement

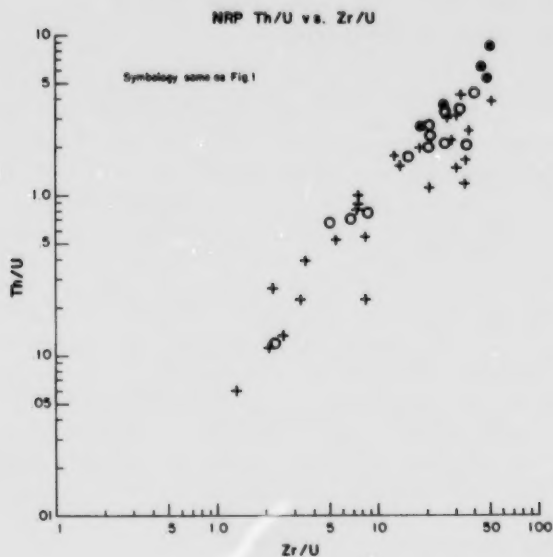


Figure 2. Th/U vs. Zr/U plot for the New Ross Pluton.

spaced airborne gamma ray spectrometric survey data collected by the Geological Survey of Canada in 1978. A previous study of the area by Ford and O'Reilly (1985), using identical radioelement data but older geological maps, left a number of high, and an extensive area of low, eU/eTh responses unexplained. However, when applied to recent bedrock mapping a definite correlation between the eU/eTh data and granitic rock type is apparent (Fig. 3). The core monzogranite characterized by a low ratio ($<.40$) is flanked by a broad area of elevated ratios ($.40 - 1.2$), which is underlain by texturally variable leucomonzogranite. Thus, the zonation implied by bedrock mapping is confirmed by airborne radiometric data. The highest (>1.2) eU/eTh ratios correlate directly with the occurrence of finer grained, often extensively metasomatized phases, commonly containing mineralization (O'Reilly et al., 1982; MacDonald et al., 1987). The few areas of high eU/eTh ratio with no confirmed bedrock expression exist in areas with little or no outcrop exposure. Pebble counts from till samples in these areas by Finck and

Graves (personal communication) indicate almost 100% fine grained leucogranite. Whether these small bodies represent later intrusions or hydrothermally altered textural equivalents, as suggested by Ford and O'Reilly (1985), cannot be determined with the existing data.

The common occurrence of these finer grained bodies within embayments or protuberances of the leucomonzogranite phase may indicate that they represent hydrothermally altered equivalents. Contact relationships are enigmatic, with the same body exhibiting both sharp and gradational contacts, as noted by Charest (1976) for porphyry bodies in the New Ross area. However, Figures 1 and 2 suggest that two distinct populations of finer grained phases exist, based on their U content (ppm) and degree of magmatic differentiation.

For the New Ross area, the use of airborne radiometric surveys, especially the eU/eTh data, provides an accurate reflection of regional bedrock geology and serves as a reliable reconnaissance mapping tool.

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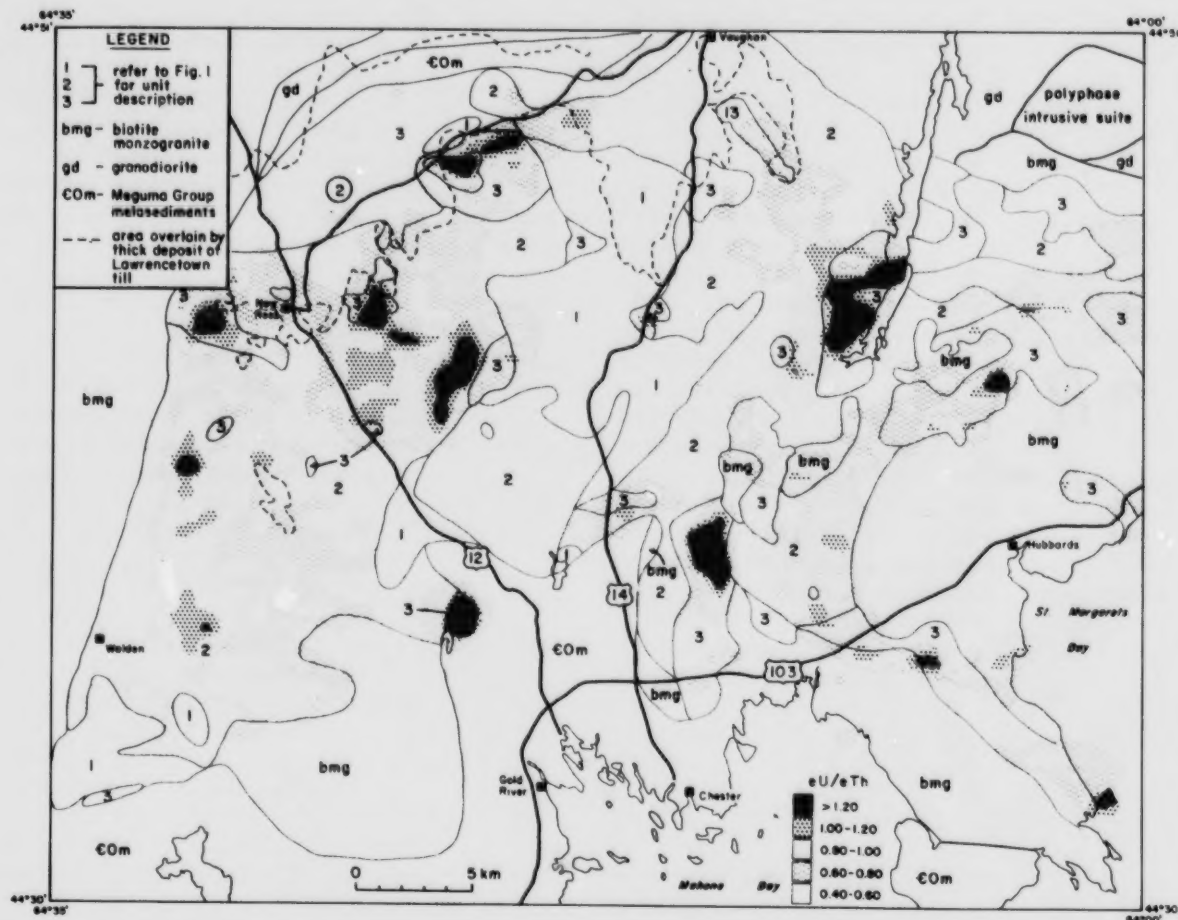


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JOINT PATTERNS IN THE SOUTH MOUNTAIN BATHOLITH¹

R. J. Horne, M. A. MacDonald, M. C. Corey and L. J. Ham

INTRODUCTION

During geological mapping of the eastern portion of the South Mountain Batholith (SMB) several structural elements, including primary flow features, joints, dykes, veins and faults were recorded. These data have been compiled and analyzed in order to evaluate the patterns defined by these features and to address the formation of any such patterns. This report briefly presents the results of this evaluation, in particular the orientations of joints, dykes and veins.

GENERAL GEOLOGY

Granitoid rocks of the eastern SMB have been subdivided into eight lithologic groups (MacDonald et al., 1987), each of which is represented by several discrete bodies throughout the Batholith, indicating a complex intrusive history. Regionally, the study area comprises three plutonic centres, referred to as the Halifax Pluton (HP), the New Ross Pluton (NRP) and the East Dalhousie Pluton (EDP). These plutons are represented on the geology map in MacDonald et al. (1987), with the HP in the eastern extreme of the study area, the NRP in the central area and the EDP at the western end. Field relationships indicate that the NRP and EDP, both of which consist primarily of monzogranitic rocks, are intrusive into, and therefore younger than, a regional envelope of biotite monzogranite and granodiorite. Age dating has confirmed this temporal

relationship for the NRP (Clarke and Halliday, 1980). The relationship of the HP to the rest of the SMB is unclear, as the HP appears to be in both gradational and intrusive contact with the 'envelope' rocks.

The SMB has intruded Cambro-Ordovician metasediments of the Meguma Group and Ordovician to Lower Devonian metasediments and metavolcanics of the White Rock, Kentville, New Canaan, and Torbrook Formations which conformably overlie the Meguma Group. This sequence was deformed into northeast-trending upright folds during the Acadian Orogeny. Sharp intrusive contacts with country rock, a lack of significant distortion or deflection of regional structures and an abundance of xenoliths suggest magmatic stoping was the dominant mechanism of intrusion (Wright, 1931; McKenzie and Clarke, 1976).

PRIMARY FLOW FEATURES

Primary flow features include schlieren banding, flow concentrations of megacrysts and xenoliths, and parallel alignment of megacrysts. With the following exceptions, these features are not well developed within the SMB, probably reflecting the passive style of intrusion.

A crude circular pattern coinciding with the general shape of the HP is defined by the orientation of schlieren banding and parallelism of megacrysts in the rocks near the margin of the HP. A similar circular pattern

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is developed within the NRP and is defined by a weak alignment of megacrysts. A regional northeast-trending fabric is developed within the EDP and biotite monzogranite and granodiorite west of the EDP. Aligned megacrysts and xenoliths, biotite foliation and schlieren banding define this fabric.

JOINTS, DYKES AND VEINS

The term joint herein refers to planar fractures, including those which host dykes or veins. Dyke rocks, in order of decreasing abundance, include aplite, pegmatite, aplite/pegmatite and minor granitoid rock types. Veins refer strictly to quartz veins. Limitations imposed on the dataset are: (1) measurements were somewhat subjective, as only the most prominent joints were measured, (2) the density of data is variable and (3) a lack of vertical sections restricted the proper appraisal of flat-lying joints.

In order to evaluate any distinct structural trends within the three plutons, stereonet plots of joints within each pluton were created (Fig. 1a, b, c). These plots show similar patterns with northwest/steep and northeast/steep trends dominating each of the plutons. Although a stereonet plot of all joint data from the SMB has not yet been compiled, a series of plots which encompasses the entire dataset shows comparable trends to those above.

Northwest-trending joints commonly form the dominant joint set. These joints have well developed planar surfaces, good continuity and regular spacing. Joint surfaces are often encrusted with hydrothermal minerals (sericite, chlorite, fluorite, calcite) and these joints are the dominant host of veins and dykes. This relationship is illustrated by coincidence of the trends shown for veins and dykes in Figure 1d and 1e with the northwest trend outlined in each of the plutons.

The existence of dykes and veins is generally accepted as evidence of a primary origin for joints (Balk, 1937; Hutchinson, 1956; Marre, 1985). Within the SMB, the proximity of mineralized veins and dykes to late-stage leucocratic rocks, coupled with limited geochronological dating (Farley, 1978) suggests that this mineralization is related to late-state magmatic-hydrothermal processes (McKenzie, 1974; Farley, 1978; Charest, 1979; Logothetis, 1984). Many of these mineralized veins and dykes are controlled by the northwest joint set outlined here, suggesting they developed shortly after crystallization.

Northeast-trending joints are generally poorly developed, have irregular joint planes and are irregularly spaced. Locally they become tightly spaced and develop into fracture cleavage. Fracture cleavage is most commonly developed in the leucomonzogranitic units and tends to be accompanied by intense hematization. Hematization in these zones has been interpreted by Logothetis (1984) as a late-stage magmatic phenomenon, suggesting a primary origin for these joints. Quartz veins rarely occur in northeast-trending joints, and dykes are more abundant within northwest-trending joints.

The relationship between the two dominant joint sets is locally well exposed. In several locations, well developed northwest-trending joints, locally hosting veins or dykes, crosscut a subordinate set of poorly developed northeast-trending joints, which locally develop into altered zones of fracture cleavage. Locally, the reverse is true suggesting the two joint sets developed closely in time.

DISCUSSION

The development of primary joints within granitic rocks is well established in terms of flow dynamics

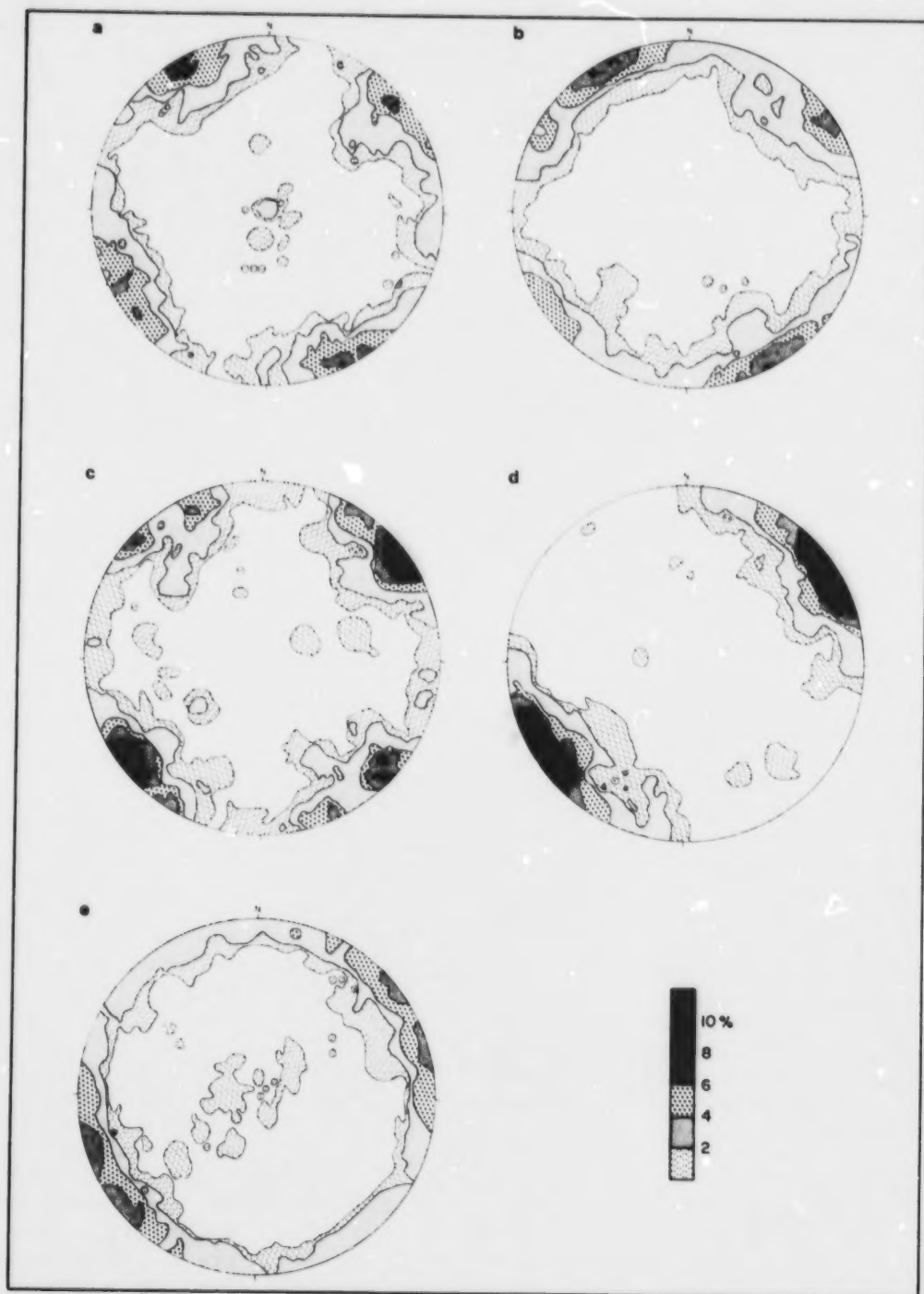


Figure 1. Contour plot of poles to (a) joints (n=317) within the Hp, (b) joints (n=700) within the NRP, (c) joints (n=183) within the EDP, (d) dykes (n=640) within the SMB and (e) veins (n=381) within the SMB, per 1% area of an equal area net.

with jointing developed perpendicular, parallel and oblique to the direction of flow (Balk, 1937; Marre, 1986). The identification of these primary joints is dependent on recognition of flow features. The scarcity of flow features in the study area, however, makes such a correlation difficult. In general terms, joint patterns for the HP and NRP, where crude circular flow patterns exist, might be expected to be radial and concentric, reflecting the flow patterns. In contrast, more restricted joint patterns would be expected for the EDP where flow patterns are regionally linear. The joint patterns defined within the map area are not consistent with these expectations and cannot be explained in terms of any internal parameters, either temporal or spatial, within the SMB. Instead, these patterns seem best explained by a regional stress which was imposed uniformly over the area.

The prevalence of dykes and veins within northwest-trending joints, and relative lack of the dykes and veins in northeast-trending joints suggests the extensional component of this regional stress is NE-SW, whereas the greatest shortening occurred NW-SE. Indeed, the description of these two joint sets fits the general description of cross and longitudinal joints developed perpendicular and parallel to the direction of flow (extension) given by Balk (1937) and Marre (1986). The time of formation of these joint sets is questionable given the regional consistency, however the evidence given here suggests they are primary features developed during or shortly following crystallization.

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SOUTH MOUNTAIN BATHOLITH PROJECT: COMPOSITION OF MUSCOVITE WITHIN THE SMB¹

L. J. Ham

Muscovite or white mica occurs in variable amounts and modes of occurrence in different rock types within the South Mountain Batholith (SMB) (MacDonald et al., 1987) and compositions of these muscovites have not been systematically studied. Several distinct textural associations of muscovite within these rocks (e.g. euhedral grains, alteration products of other minerals such as biotite, cordierite and feldspar) have been recognized during previous work and during the current bedrock mapping project. This study documents the texturally different modes of occurrence of muscovite within the SMB and their chemical characteristics. For the purposes of the project, analyses were undertaken only on muscovite; compositions of other mineral phases within the rocks (biotite, plagioclase, potassium feldspar, chlorite) were not obtained.

The presence of muscovite or white mica (WM), particularly magmatic muscovite, within granitoid rocks is

indicative of peraluminous composition (Miller et al., 1981; Clarke, 1981; Speer, 1984). It has been used to indicate the depth of crystallization for a magma, since primary igneous muscovite is considered to crystallize at a minimum pressure of approximately 3 kbar (11 km), based on experimental data (Althaus et al., 1970; Miller et al., 1981). Secondary WM occurs as alteration products or as a subsolidus reaction product and the necessary pressure and temperature constraints for primary WM formation are no longer valid. Studies using primary-looking WM in certain granitic rocks have determined depths of crystallization deeper than those calculated using independent criteria. This raises doubts about whether some primary-looking WM is indeed primary.

A number of authors (Saavedra, 1978; Miller et al., 1981; Anderson and Rowley, 1981; Monier et al., 1984; Speer, 1984) have studied the chemical differences between primary and

Table 1. Criteria used for determination of primary and secondary white mica.

Miller et al. (1981)		Saavedra (1978)
LOCATION	North America and Europe 16 different peraluminous granitoid plutons (41 samples) of North America and Europe	Central Spain Peraluminous granites
CRITERIA	(1) grain size in comparison with the other obviously primary minerals (2) nature of the terminations of the grains and grain formation (clean, neat terminations, ideally with subhedral to euhedral shapes) (3) grain ideally free from inclusions and also not enclosed by minerals from which it could have been derived through alteration processes (4) overall degree of alteration of the groundmass of the rock being relatively unaltered, clean and having igneous textures	(1) different twinning from biotite when intergrown and contact between the micas well differentiated (2) good, rhombohedral form (3) well developed euhedral grains within plagioclase (4) absence of inclusions of accessory minerals, particularly those from which it could have been derived

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secondary modes of WM occurrence, using classification schemes principally based on textural criteria. These criteria are listed in Table 1. The studies have indicated that there are subtle chemical compositional differences, particularly with Ti contents, between primary and secondary WM. Titanium contents are higher in primary muscovite, Fe contents can be higher in secondary muscovite and other elements (Mg, Na, Al, Si) exhibit considerable overlap.

Eight modes of occurrence of muscovite from the SMB were analyzed in this study, with two representing the primary magmatic grouping and the other six representing subdivisions of secondary WM (subsolidus and alteration). Polished thin sections were collected by the author and colleagues from the eastern portion of the SMB during 1985 and 1986, as part of the quadrangle mapping program. A total of 110 microprobe analyses of muscovites were obtained from 17 thin sections cut from several different rock units. The eight distinctive modes of occurrence for WM within the SMB used during this study are:

Primary (P)

- (1) igneous WM (euhedral, neatly terminated grains comparable in size to other magmatic minerals);
- (2) igneous WM intergrown with biotite (different twinning; euhedral contact of muscovite against magmatic biotite);

Secondary (S)

- (3) individual grains that do not fit the 'primary igneous' textural criteria (either enclosed in other minerals or isolated within the groundmass);
- (4) WM as alteration product of biotite;
- (5) WM as alteration product of plagioclase;
- (6) WM as alteration product of potassium feldspar;

(7) WM as alteration product of cordierite;

(8) WM as alteration product of aluminosilicate (andalusite).

Ham (in press) presents a more detailed description of the criteria used to establish these textural modes. Five different rock units were involved in this study, those being: (1) granodiorite, (2) muscovite-biotite monzogranite, (3) leucomonzogranite (medium- to coarse-grained megacrystic), (4) leucomonzogranite (fine- to medium-grained equigranular) and (5) leucomonzogranite (porphyry). Complete rock descriptions of these units are given by MacDonald et al. (1987).

The Ti concentration has been documented as a main discriminator between primary and secondary muscovite (Miller et al., 1981; Anderson and Rowley, 1981; Speer, 1984; Monier et al., 1984). The SMB analyses (Fig. 1) do not systematically fall into either the primary or secondary grouping of Miller et al. (1981) (Fig. 2a) on a Ti-Na-Mg triangle. In all rock types of the SMB, muscovites traditionally thought to be secondary (i.e. alteration products of biotite and potassium feldspar) plot well within the primary field of Miller et al. (1981). Additionally, there is no systematic consistency between individual modes of occurrence and muscovite composition (i.e. alteration products of one mineral (e.g. biotite) do not display a consistent composition).

Analyses from granodiorite and biotite monzogranite samples have higher Mg values (Figs. 1a and 1b) than analyses from leucomonzogranite, although in mid-range of the triangle, compositions within all rock units overlap. Equigranular rocks (Fig. 1d) exhibit the greatest compositional variation, with some of the highest Ti

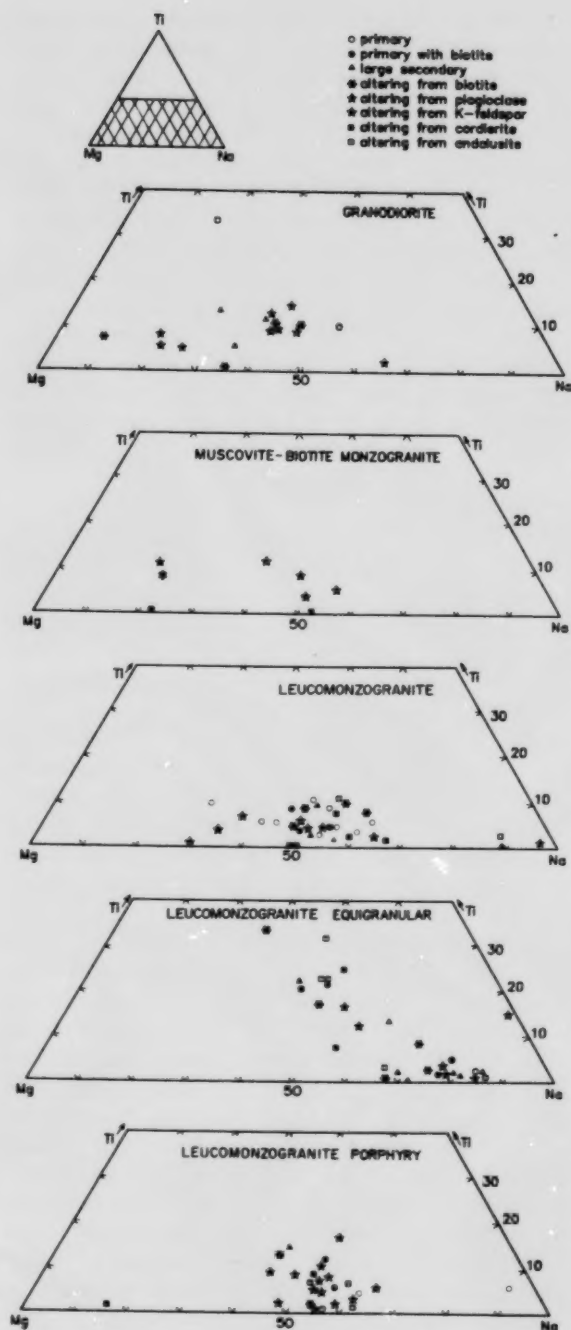


Figure 1. Compositions of different modes of occurrence of white mica within the SMB, in terms of Ti, Na and Mg (atomic proportions) from selected rock types.

and Na components. Muscovite from these rocks displays a trend toward sodium paragonitic compositions.

A similar sodium enrichment trend has been documented within the mineralized equigranular leucomonzogranite rocks of the Long Lake muscovite-quartz W-Mo-Sn deposit (Strong and Chatterjee, 1985). These compositions were postulated to represent hydrothermal muscovite. The SMB trends shown in Figure 1 contrast with the results of Miller et al. (1981; Figure 2a), who determined that

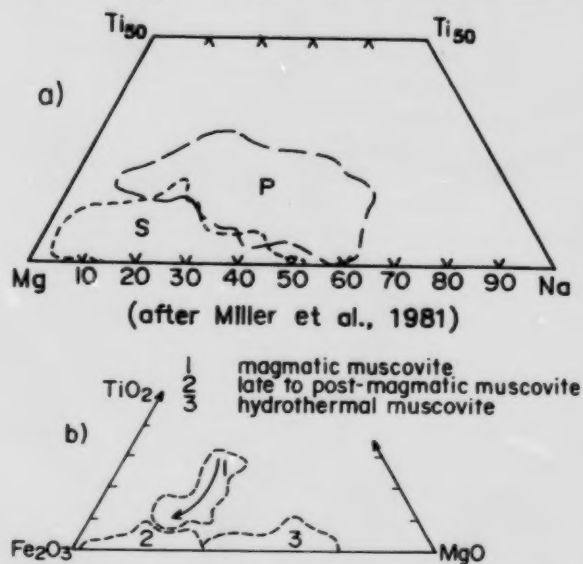


Figure 2. (a) Primary (P) and secondary (S) fields of muscovite composition, in terms of Ti, Na and Mg (atomic proportions) from selected granites of southwestern USA. (b) Compositions of white mica from the St. Julien Leucogranite (Massif Central, France) using TiO₂- (total Fe as) Fe₂O₃-MgO compositional triangle.

both the primary and secondary muscovite compositions are generally higher in Mg than Na and plot closer to the Mg apex.

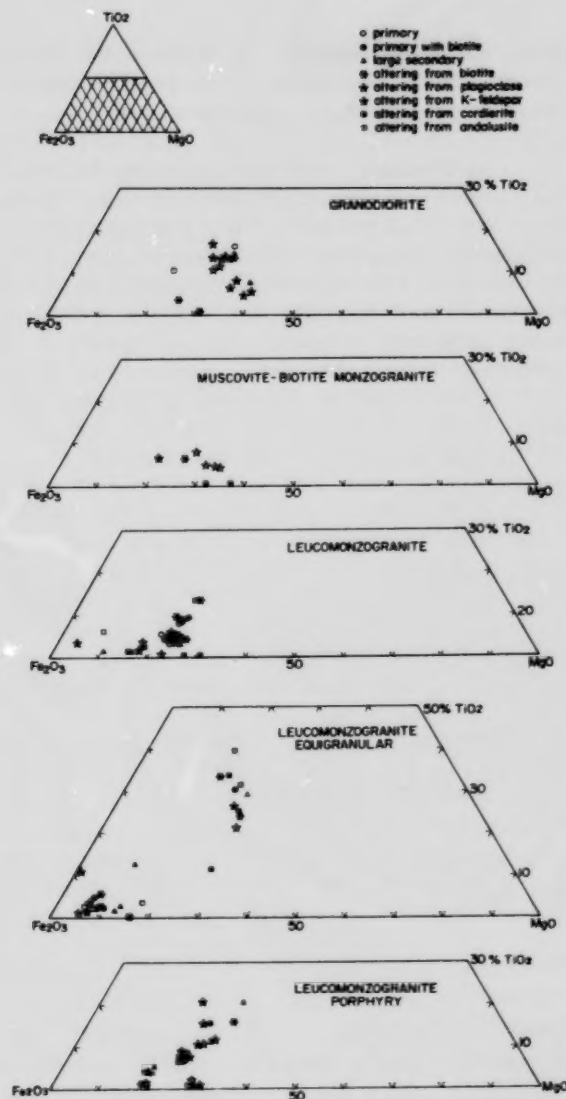


Figure 3. Compositions of different modes of occurrence of muscovite within the SMB, in terms of TiO_2 - (total Fe as) Fe_2O_3 - MgO .

Monier et al. (1984) determined three stages of crystallization of muscovite in one rock type (leucogranite) in the French Massif Central. These three stages are (1) primary or magmatic, (2) late to post-magmatic, (3) hydrothermal (Fig. 2b). Changes in muscovite composition reflect changes in the magmatic evolution of the granite.

The muscovite modes analyzed within the SMB (Fig. 3) generally fall within the lower end (i.e. less TiO_2) of Group 1 (magmatic) muscovite and within Group 2 (late to post-magmatic) muscovite. None fall within Group 3. Considerable overlap is noted between individual rock units. Equigranular leucomonzogranite samples (Fig. 3d) contain two distinct groups of muscovite, one which falls well within Group 1 and the other which falls within Group 2. However, some of the SMB samples that fall within Group 1 of Monier et al. (1984) are secondary products of other minerals such as cordierite or andalusite.

Several conclusions can be drawn about the muscovite within the SMB based on this study, even though there are parameters that additionally could be considered in future work (e.g. compositions of co-existing phases, crystal chemistry of the muscovite, trace element substitution). There is an imperfect correlation between muscovite composition and rock type. Muscovite from the biotite-rich rocks (granodiorite and muscovite-biotite monzogranite) is generally more Mg-rich, while WM within the leucomonzogranite units is more Na-rich and can be more Fe-rich. There is no systematic correlation (i.e. restricted compositional range) between individual modes of occurrence and muscovite composition. Magmatic and late to post-magmatic crystallization histories are suggested following the classification of Monier et al. (1984). However, the lack of systematic differences between the 'primary' and 'secondary' micas may suggest that there is very little primary muscovite within the SMB.

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PETROLOGICAL AND GEOCHEMICAL ASPECTS OF A ZONED PLUTON WITHIN THE SOUTH MOUNTAIN BATHOLITH, SOUTH-CENTRAL NOVA SCOTIA¹

M. A. MacDonald and R. J. Horne

INTRODUCTION

The occurrence of zoned granitic intrusions has been well documented over the past two decades (e.g. Karner, 1968; Ermanovics, 1970; Halliday et al., 1980; Ludington, 1981; Ayuso, 1986). Recent mapping in the eastern portion of the South Mountain Batholith (SMB) has outlined a zoned sequence of rock units within a discrete granitic body which will be termed the Halifax Pluton (HP) (MacDonald et al., 1987). Smith (1974) was the first to describe the granitic rocks of the HP and recognized the zoned nature of the Pluton. However, the rocks were not as rigorously divided as in the present study.

In order to understand the nature of zoning (i.e. normal versus reverse zoning) in the HP a thorough petrographic and geochemical investigation was undertaken in the winter of 1986/1987. The following is a summary of the results of that study. A full presentation of the observations and results is now in preparation (MacDonald and Horne, in press).

GENERAL GEOLOGY

The general geology of the HP is presented in Figure 1. Granitoid rocks of the HP may be divided into two sequences on the basis of field relations, texture and composition.

Sequence 1 is the zoned sequence, consisting of fine- to coarse-grained,

megacrystic to seriate textured rocks with variable modal percentages of biotite, cordierite, muscovite and alkali feldspar megacrysts (i.e. euhedral to subhedral crystals generally > 2.5 cm in length). Cross-section A-B in Figure 1 displays the symmetrical distribution of rock units in the HP. From the northern contact with metasedimentary rocks (i.e. B) to the core, the sequence includes biotite granodiorite (DCgda); biotite monzogranite (DCmgSL); muscovite-cordierite-biotite leucomonzogranite (DClmHX); cordierite-biotite monzogranite (DCmgHF_a); and biotite monzogranite (DCmgHF). Both gradational and intrusive contacts were observed between individual units, indicating a complex intrusive history for the HP.

Sequence 2, which comprises the Tantallon Intrusive Suite (TIS) and porphyry (DCm_gp), contains predominantly fine- to medium-grained rocks (minor coarse grained) with porphyritic, equigranular, aplitic and pegmatitic textures. Muscovite is an essential constituent and andalusite is a common accessory. Field evidence indicates that sequence 2 postdates the zoned sequence 1, with contacts between the two sequences being ubiquitously intrusive.

PETROLOGY

Results of a complete petrographic study of approximately 250 thin sections are presented in

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A geochemical cross-section (line A-B)

modal percentage of biotite and a concomitant increase in the percentages of alkali feldspar megacrysts, cordierite and muscovite. From DClmHX to the core of the Pluton (i.e. DCmgHF_a-DCmgHF) these trends are reversed, with increasing biotite and decreasing muscovite, cordierite and alkali feldspar megacrysts.

(1) Variations were observed in modal mineralogy of the units. Traversing inward from the margin of the Pluton (i.e. DCgda-DCmgSL-DClmHX) there is a substantial decrease in the

Table 1. Petrography of the Halifax Pluton.

UNIT	ROCK TYPE	GRAIN SIZE	TEXTURE	MEGACRYSTIC	PHENOCRYSTIC	PLAGIOCLASE COMPOSITION	ZONING	INTERGROWTH	ALTA	ENSOULT	MICROCL	BIOTITE	ALT	MUSCOVITE	REPPL	BIH	CONDIERITE FRESH	ALT	GARNET	AMALUSITE
DCyda	Qz10	f-m	MEGA	0 - 1		An 15-33	2>1>3	common	0 - 1	1		1 12-15	0 - 1	trace	KP		0 - trace	PI		
DCySL & DCySP	Qz10	m - c	MEGA	1 > 2		An 11-36	2>1>3 >>0	common	0 - 1	1>>2	trace	1 10-12	0 - 1	trace - 1	KP>>CD	trace	0 - <1	PI>CH >PI	common occurrence trace abundance	
DCyHP	Qz10	f - c	MEGA (SERI)	1		An 3-30	1>2>3 >>0	common	0 - 1	1>2 >>0		1-2 8-10	1(2)	trace - 1 locally 2-3	KP>PL >CD	trace	0 - 1	PI>CH >PI	trace occurrence abundance	X
DCyMK	Qz10	f - c	MEGA	1 - 2		An 2-27	1>0>2	trace	2 - 3	1=2	trace	2 >2-5	1 - 4	1 - 2 locally 3 - 4	KP>CD >PL	common	0 - >PI	MU>CH >>PI	trace occurrence + abundance	X
DCyT & c	Qz10	f, m, c	EQUI PORP MEGA SACH	0 > 1	QZ> >PI>BI >>CD	An 1-15	0>1	none	2 - 3	0>1	common	2-3 >1-4	1 - 4 avg 2-3	1-4	KP>CD >BI	common	common occurrence trace abundance	MU>CH >>PI		common occurrence trace - locally 2
b	Qz10	f-c	PORP	1	KP>QZ >PL>CD	An 16-28*	1>3*	none	2-3	1>0	minor	2 4-5	3 - 4	2 - 3	KP>PL >>CD	trace	<1-2	MU>PI		
DCySP	Qz10	f-m	PORP (GRAP)	1	PL>QZ >KP>>BI	An 15-34*	0>1	none	0-4 avg 2	0>1	none	2 >1-5	1 - 3	<2 - >10	KP>>CD	common	0 - 1	PI>MU >CH		common occurrence trace abundance
DCySP	Qz10	f-m	PORP	0	PL>QZ >KP	An 15-30	2>1*	common	0-2	1	none	1 12-15	0 - 1	trace - 1	PL>KP >>CD	trace	0 - trace	PI>MU	trace occurrence + abundance	X

EXPLANATION

UNIT refers to map code

- QZ10 - quartz; QZ - quartz; KP - alkali feldspar; PL - plagioclase; BI - biotite; MU - muscovite; CD - cordierite; CH - garnet
- f - fine; m - medium; c - coarse; > - greater than; < - less than; = - equal to
- QZ10 - quartz; QZ - quartz; KP - alkali feldspar; PL - plagioclase; BI - biotite; MU - muscovite; CD - cordierite; CH - garnet
- f - fine; m - medium; c - coarse; > - greater than; < - less than; = - equal to

- MEGACRYSTIC - megacrystic; PORP - porphyritic; MEGA - megacrystic; SERI - seriate; RACH - saccharoidal; PRGM - pegmatitic; GRAP - graphic
- PHENOCRYSTIC - phenocrystic; slightly micaceous (<15%); 2 - very micaceous (15-50%)
- PLAGIOCLASE - composition - indicates phenocryst composition
- QZ10 - quartz; QZ - quartz; KP - alkali feldspar; PL - plagioclase; BI - biotite; MU - muscovite; CD - cordierite; CH - garnet
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- QZ10 - quartz; QZ - quartz; KP - alkali feldspar; PL - plagioclase; BI - biotite; MU - muscovite; CD - cordierite; CH - garnet
- f - fine; m - medium; c - coarse; > - greater than; < - less than; = - equal to
- QZ10 - quartz; QZ - quartz; KP - alkali feldspar; PL - plagioclase; BI - biotite; MU - muscovite; CD - cordierite; CH - garnet
- f - fine; m - medium; c - coarse; > - greater than; < - less than; = - equal to

LIST OF MINERAL ABBREVIATIONS

QZ - quartz; KP - alkali feldspar; PL - plagioclase; BI - biotite; MU - muscovite; CD - cordierite; CH - garnet

NOTES:

- All quartz displays undulose extinction and commonly development of subgrains
- All rocks contain quartz + alkali feldspar + plagioclase

Table 2. Geochemistry and normative mineralogy of the Halifax Pluton and the central SMB.

	Sequence 1										Sequence 2				McKenzie and Clarke (1975)									
UNIT	DCgda		DCwSL		DCwP		DCwHF		DCwKX		DCwTa,c		DCwTb		DCwpp		DCwgap		Granodiorite		Monzogranite		Dyke Rocks	
Major Elements (%)	$\bar{X}$ N = 10	SD	$\bar{X}$ N = 9	SD	$\bar{X}$ N = 10	SD	$\bar{X}$ N = 23	SD	$\bar{X}$ N = 25	SD	$\bar{X}$ N = 17	SD	$\bar{X}$ N = 4	SD	$\bar{X}$ N = 5	SD	$\bar{X}$ N = 2	SD	$\bar{X}$ N = 10	SD	$\bar{X}$ N = 10	SD	$\bar{X}$ N = 10	SD
SiO ₂	68.11	0.71	69.30	1.18	69.80	0.43	71.33	1.34	72.95	0.80	74.55	0.69	71.49		74.69		69.03		69.13	1.32	73.42	1.27	74.38	1.21
TiO ₂	0.59	0.02	0.48	0.10	0.40	0.05	0.40	0.08	0.20	0.07	0.09	0.04	0.31		0.18		0.42		0.62	0.10	0.24	0.09	0.15	0.09
Al ₂ O ₃	15.52	0.37	15.11	0.19	15.10	0.43	14.49	0.41	14.32	0.33	14.22	0.34	14.91		13.99		14.74		14.37	0.33	13.74	0.40	13.71	0.42
Fe ₂ O ₃ (tot)	4.18	0.19	3.59	0.66	3.06	0.29	2.94	0.47	2.09	0.38	1.34	0.20	2.46		1.95		3.24		4.48	0.67	2.04	0.30	1.47	0.39
MnO	0.09	0.01	0.08	0.01	0.07	0.005	0.06	0.01	0.05	0.01	0.05	0.01	0.05		0.05		0.07		0.10	0.01	0.11	0.15	0.04	0.01
MgO	1.50	0.08	1.33	0.18	1.16	0.11	1.04	0.09	0.77	0.11	0.58	0.11	1.04		0.74		2.86		1.05	0.20	0.35	0.12	0.19	0.15
CaO	1.79	0.11	1.40	0.32	1.30	0.12	1.07	0.24	0.64	0.19	0.36	0.06	0.83		0.45		1.76		1.98	0.23	0.67	0.19	0.52	0.16
MgO	3.49	0.05	3.35	0.17	3.22	0.15	3.22	0.13	3.22	0.15	3.46	0.39	3.52		3.14		4.09		3.28	9.19	3.36	0.12	3.58	0.47
K ₂ O	3.80	0.13	4.29	0.31	4.70	0.34	4.40	0.16	4.66	0.18	4.42	0.21	4.19		4.48		3.81		3.84	0.28	4.75	0.24	4.53	0.45
P ₂ O ₅	0.19	0.01	0.19	0.01	0.16	0.02	0.25	0.02	0.22	0.03	0.25	0.07	0.26		0.21		0.20		0.09	0.03	0.12	0.08	0.16	0.10
Li ₂ O	0.65	0.12	0.62	0.13	0.66	0.13	0.71	0.10	0.63	0.11	0.68	0.12	0.97		0.08		0.60		0.88	0.14	0.76	0.15	0.78	0.10
TOTAL	99.93	0.25	99.76	0.37	99.67	0.28	99.94	0.26	99.80	0.34	99.97	0.39	100.04		100.70		100.85		99.38	0.56	99.33	0.47	99.42	1.15

*SD - Standard deviation not calculated for MC9

C.I.P.W. NORM (%)

QF	27.94	29.21	29.26	32.89	34.79	36.88	32.71	37.87	23.14	30.13	34.50	35.73
OR	22.62	25.57	28.11	26.21	27.77	26.24	24.99	26.50	22.46	22.94	28.41	27.11
AB	29.75	28.59	27.51	27.46	27.48	29.48	30.06	26.60	24.53	28.06	28.78	30.68
AK	7.70	5.75	5.46	3.70	1.75	0.10	2.44	0.86	7.41	9.34	2.57	1.55
C	2.89	2.89	2.76	3.11	3.37	3.74	3.73	3.66	1.16	1.45	2.17	2.39
BN	3.76	3.34	2.94	2.61	1.93	1.48	2.59	1.82	7.11	2.64	0.88	0.48
IL	0.17	0.17	0.15	0.13	0.13	0.11	0.11	0.13	0.15	0.22	0.24	0.09
HN	4.21	3.62	3.10	2.96	2.11	1.35	2.48	1.95	3.23	4.49	2.05	1.48
NY	3.76	3.34	2.94	2.61	1.93	1.48	2.59	1.82	7.11	2.64	0.88	0.48
HU	0.49	0.39	0.32	0.34	0.13	0.02	0.26	0.11	0.34	0.51	0.12	0.11
AP	0.45	0.45	0.38	0.60	0.53	0.60	0.62	0.50	0.47	0.22	0.29	0.38
TTDI*	83.21	86.26	87.64	89.66	93.42	96.34	91.50	94.63	81.29	82.59	93.85	95.91

*Thornton Tuttle Differentiation Index

UNIT	DCgda	DCwSL	DCwP	DCwHF	DCwKX	DCwTa,c	DCwTb	DCwpp	DCwgap	Granodiorite	Monzogranite	Dyke Rocks
Trace Elements ppm	$\bar{X}$ SD	$\bar{X}$ SD	$\bar{X}$ SD	$\bar{X}$ SD	$\bar{X}$ SD	$\bar{X}$ SD	$\bar{X}$ SD	$\bar{X}$ SD	$\bar{X}$ SD	$\bar{X}$ SD	$\bar{X}$ SD	$\bar{X}$ SD
Ba	588 84	474 149	442 123	355 103	208 92	59 85	258	137	354	691 79	253 134	131 155
Rb	164 17	203 30	194 17	238 27	275 42	349 101	256	286	201	145 17	334 92	451 208
Sr	171 22	122 35	116 26	94 27	57 27	18 13	71	34	120	141 25	11 18	10 18
HF	6 0.5	4 1.3	4 0.7	4 1.0	3 1.0	1 0.5	3	2	3			
Zr	177 14	148 26	128 19	132 19	86 23	46 13	103	73	119	210 44	85 35	34 43
Ta	1.1 0.2	1.2 1.0	1.1 0.1	1.7 0.3	1.8 0.5	2.6 1.1	2.0	1.9	1.3			
Nb	12 0.9	12 1.0	10 0.6	14 1.5	11 1.4	11 3.0	13	11	11			
Sc	9.4 1.2	7.1 1.9	6.2 1.2	5.9 1.1	4.0 0.8	2.8 0.8	4.7	3.7	7.1			
V	44 5	31 9	25 6	28 8	12 6	3 2	20		35			
La	34 3	28 9	25 5	24 4	15 5	5 3	17	12	21			
Y	32 3	31 2	29 4	25 3	23 4	18 4	20	23	22			
Th	12.3 1.3	11.5 1.0	11.2 1.5	11.3 1.4	8.3 2.0	3.9 1.3	9.0	6.5	10.0			
U	3.0 0.5	3.5 1.0	3.1 0.7	4.3 1.5	5.8 2.5	10.3 4.7	5.3	4.2	4.0			
Li	76 13	96 23	76 10	90 11	95 25	112 65	80	89	94			
F	645 111	699 219	571 70	691 98	753 194	742 377	1003	553	650			
B	26 8	34 16	27 6	30 6	34 23	26 5	30	37	25			
As	4.6 7.2	1.8 5.7	2.3 0.9	2.2 1.1	3.7 3.6	5.7 7.5	6.5	3.9	4.4			
Au*	6 5	9 16	7 6	10 11	12 10	19 20	12	7	20			
Sn	5 3	8 10	7 4	10 3	12 5	21 10	19	10	13	11 3	16 7	24 13
W	1 0.3	1 7.2	1 0	2 1.1	2 1.9	5 2.3	4	11	1			
Cu	1 3	4 5	1 2	1 3	0 1	1 2	1	1	2			
Pb	23 4	23 3	27 9	26 15	21 3	20 5	21	19	16			
Zn	70 12	66 15	64 27	71 43	51 15	43 18	55	57	58	69 8	60 10	50 16

*ppb

(2) The type of zoning in individual plagioclase crystals varies from oscillatory zoning at the margin of the Pluton to normal zoning and unzoned albite in DC1mHX and to normal and oscillatory zoning in the centre of the Pluton.

(3) The presence of myrmekite rims on individual plagioclase crystals is a common feature both at the margin of the HP (e.g. DCgda, DCmgSL and DCmgP) and near the core of the HP (e.g. DCmgHFa and DCmgHF). This feature is generally absent in DC1mHX.

(4) The type and abundance of perthite exsolution varies from rod and bead albite (generally 2-10% of individual crystals) near the margin and core of the pluton to common patch perthite (up to 30% albite in individual crystals) in the intermediate zone (i.e. DClmHX).

(5) Deuteric alteration effects (i.e. pervasive autometasomatism) vary across the HP and include chloritization of biotite, sericitization of plagioclase (especially in calcic cores) and alkali feldspar, and replacement of plagioclase by alkali feldspar. Alteration effects are minimal at the margins and core areas of the HP and increase toward the intermediate portion of the pluton (i.e. DC1mHX).

GEOCHEMISTRY

One hundred sixteen representative samples from all map units were collected, pulverized and analyzed for major elements and a suite of 23 trace elements. Analytical results and CIPW normative calculations are presented in Table 2 along with average results from McKenzie and Clarke (1975) for the central portion of the SMB. Rocks from this study were compared with rocks of similar composition from the central SMB as determined by similar Thornton Tuttle Differentiation Indices (e.g. granodiorite-adamellite-dyke rocks from

the central SMB (McKenzie and Clarke, 1975) were compared with DCgda-DClmHX-DClmTa,c, respectively, from the HP). It is apparent from Table 2 that the HP is enriched in P_2O_5 , MgO and normative corundum when compared to the central SMB. The mineralogical expression of the high MgO and normative corundum is the abundance of Mg-rich cordierite (up to >5%) in some rocks from sequence 1. Cordierite is not a major constituent in the granitic rocks of the central SMB but rather is present in local

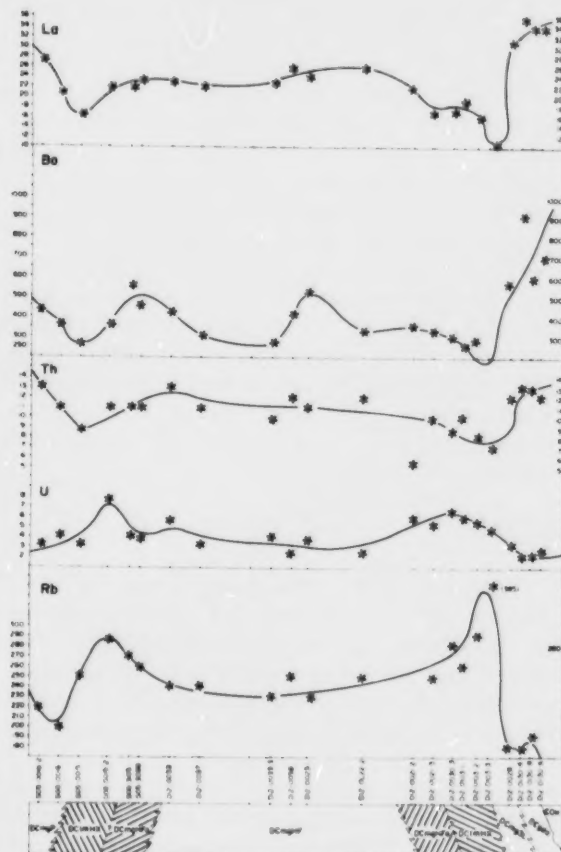


Figure 2. Geochemical traverse across the zoned Halifax Pluton for Rb, U, Th, Ba and La. Note the reversal of the geochemical trends over the core of the Pluton. All elements in ppm. Samples were collected near cross-section line A-B (Fig. 1).

concentrations or in trace amounts. The common occurrence of andalusite in sequence 2 rocks is also an expression of high normative corundum. The authors feel that caution should be exercised when comparing results from differing analytical techniques and laboratories and some of the above comparisons may in fact be more apparent than real. However, mineralogical differences between the HP and central SMB support some of the geological comparisons.

In order to quantify the extent of chemical zoning in rocks of sequence 1, a geochemical cross-section has been prepared using 22 samples from the approximate area of the A-B line in Figure 1. The results for a selected suite of elements are presented in Figure 2. Elements which are generally considered to be 'compatible' in granitic melts (e.g. Ba, Th, La) display a smooth decrease from the margin of the HP (i.e. DCgda to DCImHX) followed by an increase toward the core (i.e. DCmgHF). Conversely, elements generally considered to be 'incompatible' (i.e. Rb, U) show an inverse pattern.

SUMMARY

This report outlines some of the results of an extensive petrological and geochemical study which confirms that the HP represents a discrete, geochemically and petrologically zoned pluton within the SMB. The outer margin of the pluton is normally zoned, i.e. increasingly evolved from the margin inward, whereas the core of the pluton displays a slight reversal of these patterns.

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GEOCHEMISTRY OF THE GRANITE TILL SHEET OVERLYING THE EASTERN SOUTH MOUNTAIN BATHOLITH¹

R. M. Graves, P. W. Finck and F. J. Boner

INTRODUCTION

The South Mountain Batholith (SMB) Pleistocene Mapping Project is part of the 1984-1989 Canada - Nova Scotia Mineral Development Agreement. The general aim of the Pleistocene Mapping Project is to assist in bedrock mapping and aid in the evaluation of the economic potential of the SMB by studying the glacial geology, till clast geology and till geochemistry. This report is concerned with the sampling and analysis of till for the purpose of intersecting mineral dispersal trains and delineating previously unknown regions of economic interest. The study area is located over granitic terrain on NTS map sheets 11D/05, 11D/12, 11D/13 and 21A/09 (Fig. 1).

SAMPLING AND ANALYTICAL METHODOLOGY

Glacial till was mapped and systematically sampled using available road cuts and coastal exposures, and by digging soil pits. Three hundred eighty-two granite till samples were collected across the map area on a 2 km grid and classified on the basis of colour, matrix composition, compaction, sedimentary structure and clast geology. Samples were separated into matrix and clast fractions by dry sieving in the field through 1.25 cm plastic screens.

Till matrix was submitted to the Minerals Engineering Centre (Technical

University of Nova Scotia) for sample preparation. The -50+230 fraction was obtained from 5 kg of till matrix by wet sieving. Tetrabromomethane was employed to extract the heavy minerals from this fraction. The concentrate was then analyzed for W by neutron activation (NA) and for Sn, Nb and Ta by inductively coupled plasma mass spectroscopy (ICP/MS) at XRAY Assay Laboratories Ltd. The -230 fraction of the till was also separated by wet sieving. This portion of the till was analyzed at Saint Mary's University by X-Ray fluorescence (XRF) for Ba, Rb, Sr, Y, Zn, Nb, Th, Pb, Ga, Cu, Ni, TiO₂, V and Cr and at Bondar-Clegg Ltd. by NA for the Gold + 25 elements package.

DATA PRESENTATION

Raw heavy mineral analytical values for Sn, W, Nb and Ta were weighted as in Toverud (1982) using the formula:

- Awv = Arv x W1/W2 where
- Awv = weighted analytical value (ppm)
- Arv = raw analytical value (ppm)
- W1 = weight of heavy minerals in the -50+230 fraction
- W2 = total weight of the -50+230 mesh matrix used in the heavy mineral separation.

This method of representing geochemical data corrects for (1) the problem of weight variation among heavy mineral concentrates in a till sample population and (2) unequal weight of initial sample size. Raw analytical

¹Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

values are not comparable unless normalized against the weight fraction of 'heavies' in the total till. Toverud's formula produces a calculated analytical value that represents the 'ppm level' of the element in the whole till.

Figure 1 is a multi-element anomaly value plot for a series of 9

- Av = An/Tn where
- Av = anomaly value
- An = analytical value for nth element which is greater than or equal to its threshold value
- Tn = threshold value (95th percentile) for nth element
- n = number of elements in series (9)

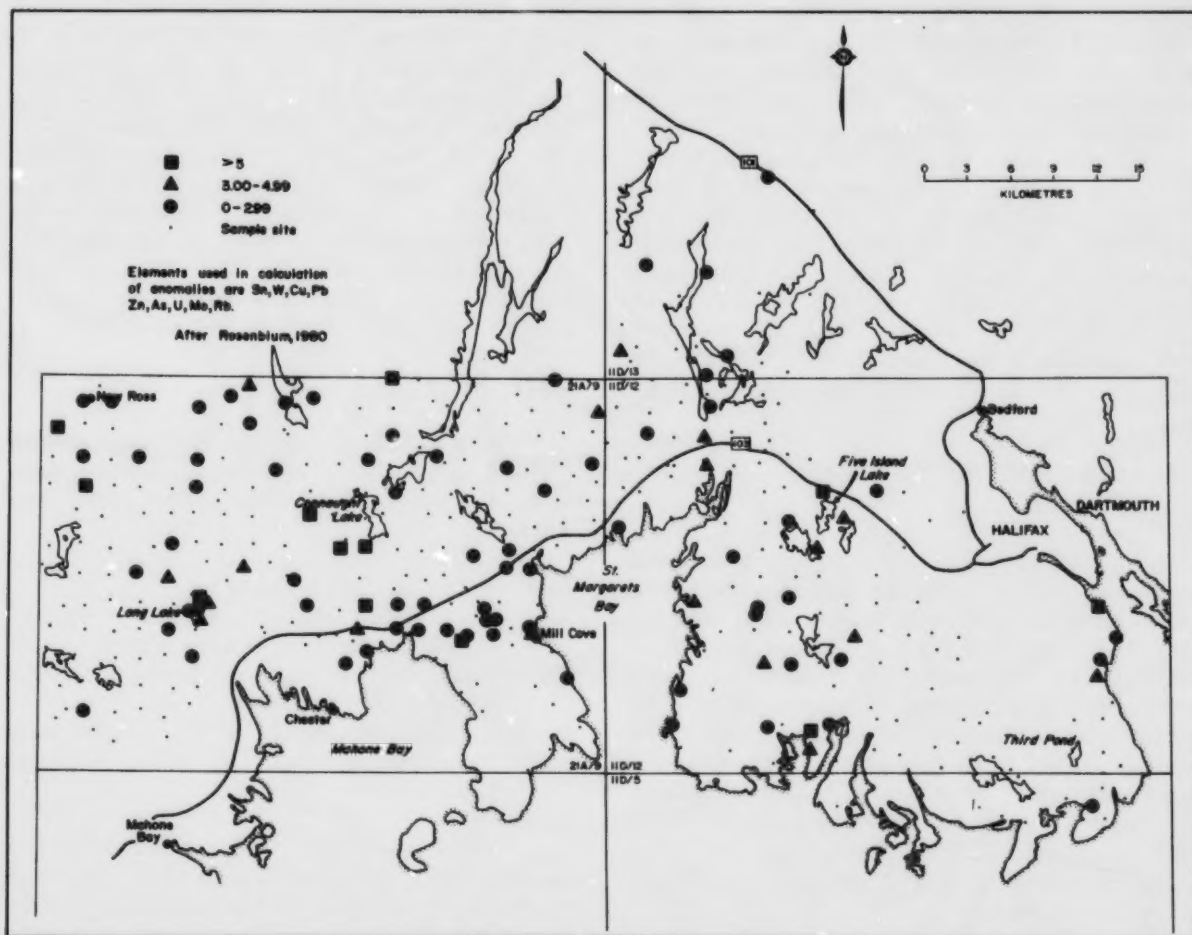


Figure 1. Multi-element anomaly plot for granite till overlying the eastern SMB.

elements (Sn, W, Cu, Pb, Zn, As, U, Mo, Rb) selected from the geochemical package. An anomaly value as defined by Rosenblum (1980) is:

Anomalous elements are arbitrarily defined as those >95th percentile of the cumulative frequency distribution. The anomaly ratios (An/Tn) are summed for the nine elements to produce an

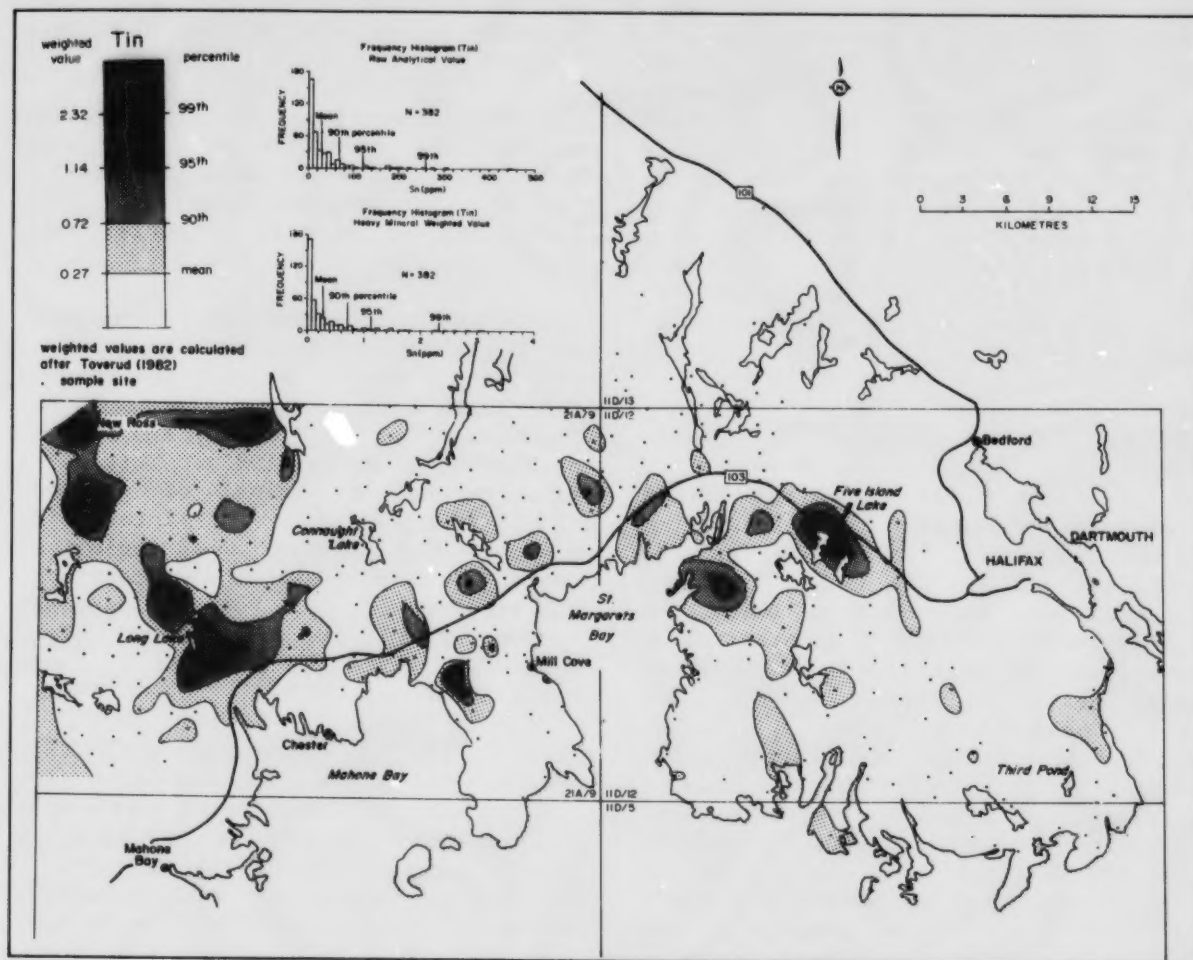


Figure 2. Weighted tin contour plot for granite till overlying the eastern SMB.

anomaly value for each sample. Large values indicate a highly anomalous concentration of an element and (or) a strong multi-element association.

MULTI-ELEMENT ASSOCIATIONS IN THE GRANITE TILL

Mineral deposits hosted by specialized granites of the South Mountain Batholith are known to be polymetallic. Farley (1978), Charest (1976) and O'Reilly et al. (1982) have identified an extensive assemblage of sulphide and oxide mineralization connected to late stage magmatism and metasomatism in the granites. Primary

ore minerals are mainly cassiterite, scheelite or wolframite and are often associated with disseminations and veins of sphalerite, chalcopyrite, arsenopyrite, molybdenite and fluorite. The occurrence of this secondary mineral assemblage in greisens, greisenized granite, quartz veins and adjacent country rock supplies useful pathfinder elements for till prospecting on the South Mountain Batholith. Stea and O'Reilly (1982) have established that the geochemistry of indigenous tills of the Meguma Terrane is controlled principally by provenance. Tills derived from greywacke, slate or granite bedrock

display a chemical signature related to their source. Mineralization within these rock types will produce metal anomalies in the till. Labile sulphide minerals are partially or completely oxidized in the weathering zone of the porous sandy tills. Subsequently, the metal cations are adsorbed to clay particles. Analysis of this fine fraction will give indications of sulphide mineralization, if present in the till (Shilts, 1975).

INTERPRETATION

By using this multi-element enrichment exhibited by granite related mineralization, seven areas of anomalous till values (Figs. 1, 2 and 3) that are suspected to have been dispersed from bedrock mineralization have been identified. Three of these localities are known prospects (New Ross, Connaught Lake and Long Lake) which host boulder and (or) bedrock occurrences of cassiterite, molybdenite, scheelite, arsenopyrite, sphalerite and chalcopyrite. Connaught Lake and Long Lake have distinct multi-element dispersal patterns that relate to the known ore mineralogy as described by previous workers. O'Reilly et al. (1982) have documented the presence of disseminated scheelite and arsenopyrite in greisenized granite and the encompassing greywackes at Long Lake. Black (1980) does not describe a tin-bearing mineral but indicates a Sn enhancement (60-320 ppm) in greisens at the same prospect. At Long Lake elevated levels of Sn and W are dispersed southward (Figs. 2 and 3). Sinclair et al. (1980) report sphalerite, arsenopyrite and chalcopyrite in greisenized float west of Connaught Lake. Corey (personal communication) has identified cassiterite, chalcopyrite and arsenopyrite in quartz and greisen veins outcropping south of Connaught Lake along Highway #103. Till overlying the granite of this area is anomalous in Zn, Cu, As and W. The

bedrock source for W has not been located.

The sampling and analytical methods are effective in recognizing known showings while also delineating new areas of economic interest. Four localities of mineral potential were defined by the till survey:

(1) At Five Island Lake, coincident Sn, U, As, Zn and Mo anomalies occur in till near a contact between the Halifax Peninsula Leucomonzogranite and the Tantallon Leucomonzogranite of MacDonald and Horne (1987). This suite of elements is typical of granite-mineralized regions. The interesting element associations and geological setting, combined with the discovery of cassiterite (P. J. Rogers, personal communication) in the nearby lake system, suggests the presence of local mineralization.

(2) At Mill Cove, elevated till values of Sn, W, Zn and As exist southwest of a large airborne radiometric U/Th ratio anomaly (Geological Survey of Canada, 1981). Radiometric anomalies of equivalent intensity exist at New Ross, Long Lake, and Connaught Lake. Albitized and greisenized granite pebbles were taken from the local till sheet, in the area of the till anomalies and the radiometric anomaly. Albitization and greisenization are common metasomatic alterations associated with granite related mineralization.

(3) At Bayside, till anomalies of W, U, As, Zn, Cu and Pb were located by this survey and by Stea and Fowler (1981) in close proximity to a contact between the Harrietsfield Monzogranite and a porphyry belonging to the Tantallon Leucomonzogranite (MacDonald and Horne, 1987). Clasts at one of the sample sites are entirely Harrietsfield Monzogranite with gossan staining on the pebble surfaces. Rogers (personal communication) has identified scheelite, zincite and hoshildite

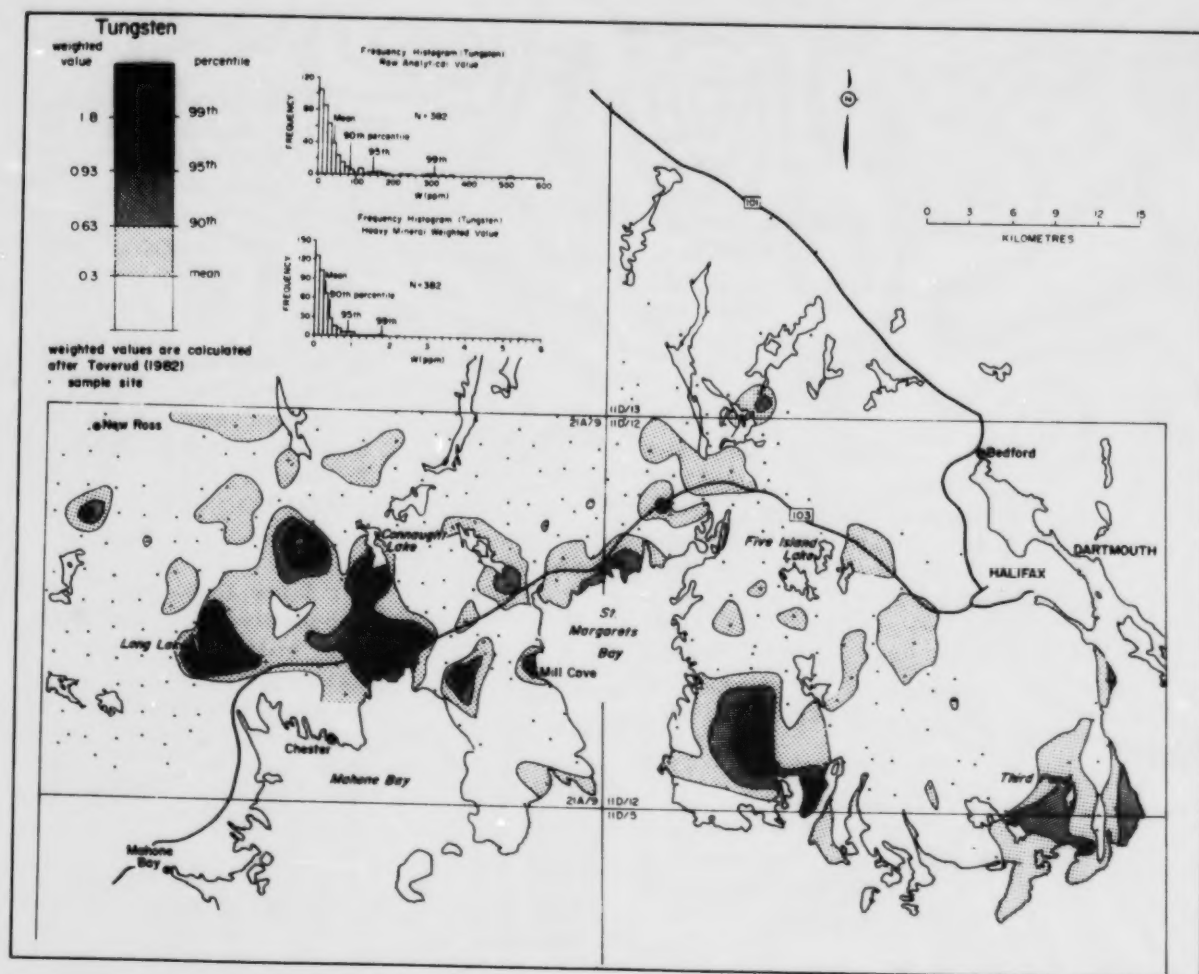


Figure 3. Weighted tungsten contour plot for granite till overlying the eastern SMB.

(SnPbO₂) in sediments from Power Lake, 3 km northwest of Bayside.

(4) At Third Pond, a region of elevated W values occur in a till dominated by clasts of Harrietsfield Monzogranite and lesser two-mica monzogranite and porphyry. Stea and Fowler (1981) also report anomalous W values in the till from this locality. The presence of these W anomalies supports the existence of significant bedrock mineralization. MacDonald and Horne (1985) located wolframite-bearing quartz veins 1 km west of Third Pond.

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CUMBERLAND BASIN PROJECT¹

R. C. Boehner, R. J. Ryan and D. C. Carter

Carboniferous basins are the dominant industrial mineral and energy producing areas in Nova Scotia. Commodities produced include salt, gypsum, anhydrite, limestone and coal and there are significant occurrences and deposits of celestite, barite, native sulphur, potash, petroleum and base metals. The Cumberland Basin is the largest Carboniferous structural basin in Nova Scotia (3600 km² area x 7000 m depth). It contains a complex

succession of coarse and fine grained alluvial-fluvial-lacustrine and minor evaporitic marine rocks of Devonian-Carboniferous to Early Permian age (Fig. 1).

The Cumberland Basin Project was undertaken to develop a comprehensive understanding of basin development including the stratigraphy, sedimentology, structure and the

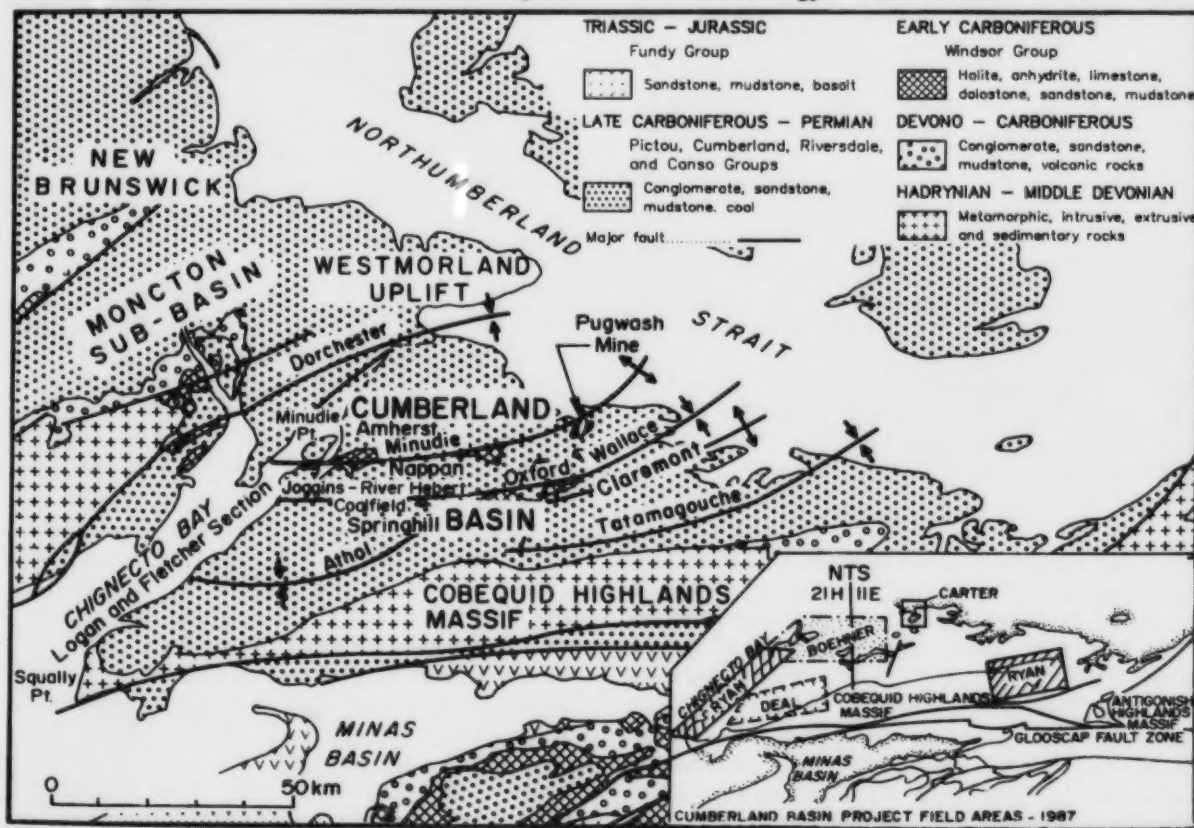


Figure 1. Location and geological map of the Cumberland Basin, northern Nova Scotia.

¹ Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

economic potential of mineral and energy resources.

Previous project activity is summarized in Boehner et al. (1987a) and focused on the eastern part (NTS 11E) of the Cumberland Basin. During the 1987 field season, mapping at a scale of 1:10 000 was completed for most (80%) of the western part of the Basin (21H). Follow-up investigations continued in the eastern part of the Basin and in the Cobequid Highlands. Project staff activities are summarized as follows:

R. Boehner - mapping in the Minudie Anticline between Chignecto Bay and the Oxford area. Contribution to the Canadian Society of Petroleum Geologists, Canadian Reef Inventory Project (Boehner et al., 1987b).

R. Ryan - reconnaissance of Devonian-Carboniferous rocks in the eastern part of the Cobequid Highlands Massif. Mapping in the Squally Point to Minudie Point shoreline, and follow-up investigation of Cu-Ag occurrences. Presentation on sediment-hosted base metal Ag deposits at the Atlantic Geoscience Society (AGS) 1987 Fredericton meeting (Ryan et al., 1987).

D. Carter - completion of detailed mapping in the Canadian Salt Company Limited Pugwash Mine. Presentations on the Pugwash Mine and Maritimes Basin Evaporites at the Geological Association of Canada - Mineralogical Association of Canada 1987 Saskatoon meeting; the Society of Economic Paleontologists and Mineralogists 1987 Austin, Texas, meeting (Carter and Boehner, 1987a, 1987b, and c); and the AGS 1987 Fredericton meeting (Carter, 1987a).

A. Deal - mapping in the Athol Syncline in the central-western part of the Cumberland Basin.

P. Rose - (and D. Carter, 1987) petrographic investigation of anhydrite units in the Pugwash Mine.

HIGHLIGHTS

Investigations were carried out in the eastern Cumberland Basin to define the relationship between the Falls and the Millville Formations. These two conglomeratic units are transitional and concordant and therefore will be considered in the future as one lithostratigraphic unit. The Nuttby Formation (eastern Cobequid Highlands Massif) was the subject of another study project during this field season. Part of the unit mapped as Nuttby Formation can be correlated with the Lower and Middle Horton Bluff Formation of the Horton Group. Paleocurrents in the Nuttby Formation area trend northerly, suggesting that the Cobequid Highlands Massif was not a significant topographic feature at the time of Horton sedimentation.

In the western Cumberland Basin, work included mapping on a 1:10 000 scale of the shore section from Minudie Point in the north to Squally Point in the south. Sedimentological observations, structure, lithofacies determinations, and sediment dispersal patterns were used to update the Logan-Fletcher section (Joggins section) exposed along the shore of Chignecto Bay. Sediment dispersal patterns indicate that dispersal was predominantly eastward. Local southerly trends exist, probably indicating dispersal away from the Caledonia Highlands Massif and New Brunswick Platform. The Cobequid Highlands Massif had little effect on the dispersal patterns in the western Cumberland Basin during the Westphalian A to C.

Geological mapping and basin analysis of the southwestern Cumberland Basin (Athol Syncline) was undertaken

and the results have been summarized by A. J. Deal for future publication.

Mapping in the Minudie Anticline-Oxford area has documented in detail the continuity and correlation of a major Windsor Group marine carbonate section previously recognized in the Pugwash - Roslin area. This unit has significant potential as a limestone-dolostone-aggregate resource if local quality and quantity can be substantiated. Mapping in the axial areas of the evaporite-cored anticlines has not been helpful in defining the detailed internal geology, but significant gypsum outcrop areas have been confirmed. Lithified fine to coarse redbeds, as discordant fracture-cavity fill (paleokarst) are present in the near surface hydration zone at depths of up to 250 m in exploration drillholes at Nappan. Their age and implications to understanding of anticline development are not known.

Underground mapping of the Pugwash salt deposit in workings of the Canadian Salt Company Limited mine at Pugwash has been completed, as has the logging and sampling of approximately 40,000 feet of drill core. This work has included a review of previous work (Evans, 1972) on the now inaccessible 630 ft level, mapping of the 730 and 830 ft levels and the 830-1000 ft level decline. Preliminary work on the overall structure and stratigraphy has previously been reported (Carter, 1986 and 1987b). The interpretation of the Pugwash salt deposit as a true piercement diapir has been further documented and efforts to correlate structures and individual units between working levels has been successful. However, the preservation of a number of seemingly fragile synsedimentary features within such a structurally complex halokinetic setting remains enigmatic. The mapping program has aided mine personnel in planning the development of the 730 ft level and the 830-1000 ft level decline.

Detailed petrographic analysis of the anhydrite units identified in the mapping program is underway and is reported elsewhere (Rose and Carter, 1987). This work appears to confirm the threefold subdivision of anhydrite exposed in the mine workings (Carter, 1986 and 1987b).

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A PRELIMINARY REPORT ON PETROGRAPHIC STUDIES OF ANHYDRITE UNITS FROM THE PUGWASH EVAPORITE DEPOSIT, PUGWASH, NOVA SCOTIA¹

P. A. Rose and D. C. Carter

Evaporites exposed in the workings of the Canadian Salt Company mine at Pugwash, Nova Scotia, have been the subject of a number of studies (Evans, 1972; Carter, 1985; 1986), however only limited petrographic work has been done on anhydrite from the Pugwash deposit (Evans, 1972). Based on internal characteristics observed macroscopically in both the mine workings and drill core, Carter (1986) subdivided the anhydrites into three units informally named the shaft, borate and third anhydrites (Carter, 1986). Previously, Evans (1972) suggested two anhydrite units, based on limited exposure on one working level, and more recently Goodman (1985) suggested ten anhydrite units. This current project was undertaken to document the anhydrites on a microscopic scale using samples collected from each of the three macroscopic anhydrite units. In all, 104 thin sections were prepared.

A preliminary examination of the thin sections was made during the summer of 1987. Preliminary results indicate significant textural differences among the three anhydrite units, supporting Carter's (1986) classification. Textural names used in the following petrographic descriptions are based on the classification scheme of Maiklem et al. (1969).

The shaft anhydrite is characterized by the following textures: (1) microcrystalline, with minor blocky, felted, aligned-felted

and lath shaped crystals; (2) nodular, showing displacive growth within carbonate and dolomite laminae; and (3) laminated, with alternations of carbonate and anhydrite. The shaft anhydrite member is also distinguished by dark organic-rich laminae, and veinlets which crosscut the laminae and are filled with coarse, crystalline anhydrite.

The borate anhydrite exhibits: (1) microcrystalline, (2) felted and (3) aligned-felted textures. A texture peculiar to the borate anhydrite is the arrangement of coarse, ragged laths of anhydrite in fibroradial groups. The presence of borate nodules as small, round, opaque aggregates of danburite crystals is unique to the borate anhydrite.

The third anhydrite is texturally similar to the borate anhydrite, exhibiting: (1) microcrystalline, (2) felted and (3) aligned-felted textures. However, the third anhydrite does not contain borate nodules and possesses more consistent and well defined alignment of anhydrite laths within aligned-felted portions. The highly ordered alignment of anhydrite laths observed in the third anhydrite is very distinctive and has not been observed in the other two anhydrite units. In contrast to the shaft and borate anhydrite units, where nodules are invariably surrounded by carbonate, the nodular mosaic portions of the third anhydrite contain microcrystalline

¹Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

nodules surrounded or rimmed by aligned-felted anhydrite crystals.

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METALLOTECTONIC PROJECT¹

J. D. Keppie and K. E. Northcote

The principles behind the proposed Metallotectonic Map of Nova Scotia were outlined previously (Keppie, 1987). Essentially, the map will depict the nature, exploration indicators and genesis of the mineral deposits in each tectonic setting. To this end, compilation of existing data is supplemented with recent and ongoing

research. An example of the Metallotectonic Map for a portion of Nova Scotia will be displayed at the Open House. The deposits with geologic environments of significant economic potential in the initial study area include Cross Roads Ohio, Stirling and Lochaber. Abstracts describing these geological environments appear below.

RARE EARTH ELEMENTS IN THE STIRLING BELT, CAPE BRETON ISLAND, AS EXPLORATION GUIDES FOR MASSIVE SULPHIDES IN LATE PRECAMBRIAN RHYOLITE

M. Zhai², J. D. Keppie and J. Dostal²

The Late Precambrian volcanic rocks of the Stirling block are mainly submarine, whereas those of the neighbouring Fourchu and East Bay Hills blocks are generally subaerial. Although all three blocks contain a bimodal volcanic suite, the geochemistry of the Stirling block basalts indicates that they are generally volcanic arc tholeiites with some calc-alkaline characteristics, whereas those in the Fourchu and East Bay Hills blocks are generally calc-alkaline. The Stirling massive sulphide deposit (Mindamar Mine) is associated

with rhyolite which has a distinctive, nearly flat rare earth element (REE) pattern with a negative Eu anomaly. This contrasts with the REE pattern from other nearby rhyolite in the Stirling block which has a light REE enrichment relative to heavy REE. The nearly flat REE pattern occurs up to 10 km from the deposit and becomes flatter closer to the deposit, providing a useful exploration tool. Such a REE pattern is characteristic of massive sulphide ore-bearing horizons in the Archean and is used as an exploration guide.

INVESTIGATION OF THE MINERAL POTENTIAL OF THE KEPPOCH FORMATION, ANTIGONISH HIGHLANDS

K. E. Northcote, J. D. Keppie, G. DeMont and J. B. Murphy³

The Keppoch Formation comprises bimodal volcanic rocks which are subaerial at the base and submarine

toward the top. The felsic rocks range from coarse volcanic breccia and agglomerate close to vents, grading

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into distal ignimbrite, medium- to fine-grained tuff and flows. The interlayered mafic rocks are of two geochemical types: continental tholeiitic and calc-alkaline. The felsic rocks appear to have resulted from anatexis of the crust produced by the rising mafic magma. The Keppoch Formation rocks are inferred to have formed in a rifted volcanic arc environment. The Keppoch Formation has economic mineral potential both in the subaerial and submarine environments. The potential of the subaerial felsic rocks is being investigated primarily

because of mineral occurrences ranging from broad pyritic zones in distal units to Cu-Zn-Pb-Ag-Au mineralization hosted in brecciated agglomerate, such as at Cross Roads Ohio (Fletcher and Faribault, 1887). Present petrographic, mineralographic, geochemical and stable isotope studies will be used to determine whether the mineralization at Cross Roads Ohio is related to Keppoch Formation volcanic centres, to subsequent tectonic events, or to mineralization contemporaneous with occurrences in nearby basal Windsor Group breccia.

LOCHABER LAKE COPPER

K. E. Northcote, G. A. O'Reilly and J. M. McMullin

Study of the Lochaber Lake copper deposit has been renewed because of its significant tonnage potential (2.29 mt drill indicated; Hooper, 1972), its undefined genesis, and because of the potential for economic mineralization to occur elsewhere in similar geologic environments.

The deposit occurs in the Arisaig Group Stonehouse Formation of Silurian (Pridolian) age (Boucot et al., 1974; Murphy, 1986), and is lithologically controlled. Mineralization is best developed in banded, argillaceous, calcareous interbeds as disseminations of chalcopyrite, with lesser bornite and chalcocite in the rock matrix. Mineralization is also developed along bedding planes and in fractures. Widely scattered quartz-carbonate veins containing dispersed blebs and disseminations of copper minerals also occur. Diabase sills or dykes cutting the sedimentary sequence are a possible but unproven source for mineralizing fluids and(or) metals.

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REGIONAL GEOCHEMICAL SURVEYS¹

P. A. Lombard and R.F. Mills

INTRODUCTION

A two year regional geochemical survey was initiated in May 1986 to sample stream sediments in the northern half of Nova Scotia (Fig. 1). Approximately 1300 localities were sampled in 1986, and 1200 stream localities were sampled in the 1987 field season. The main objective of the project is to provide heavy mineral

stream sediment and stream water analyses. The exploration database for Au and other elements not previously analyzed by other surveys will be included in the regional *Nova Scotia Geochemical Atlas*.

ANALYSIS

A flow chart showing the processes used in sample preparation and analysis

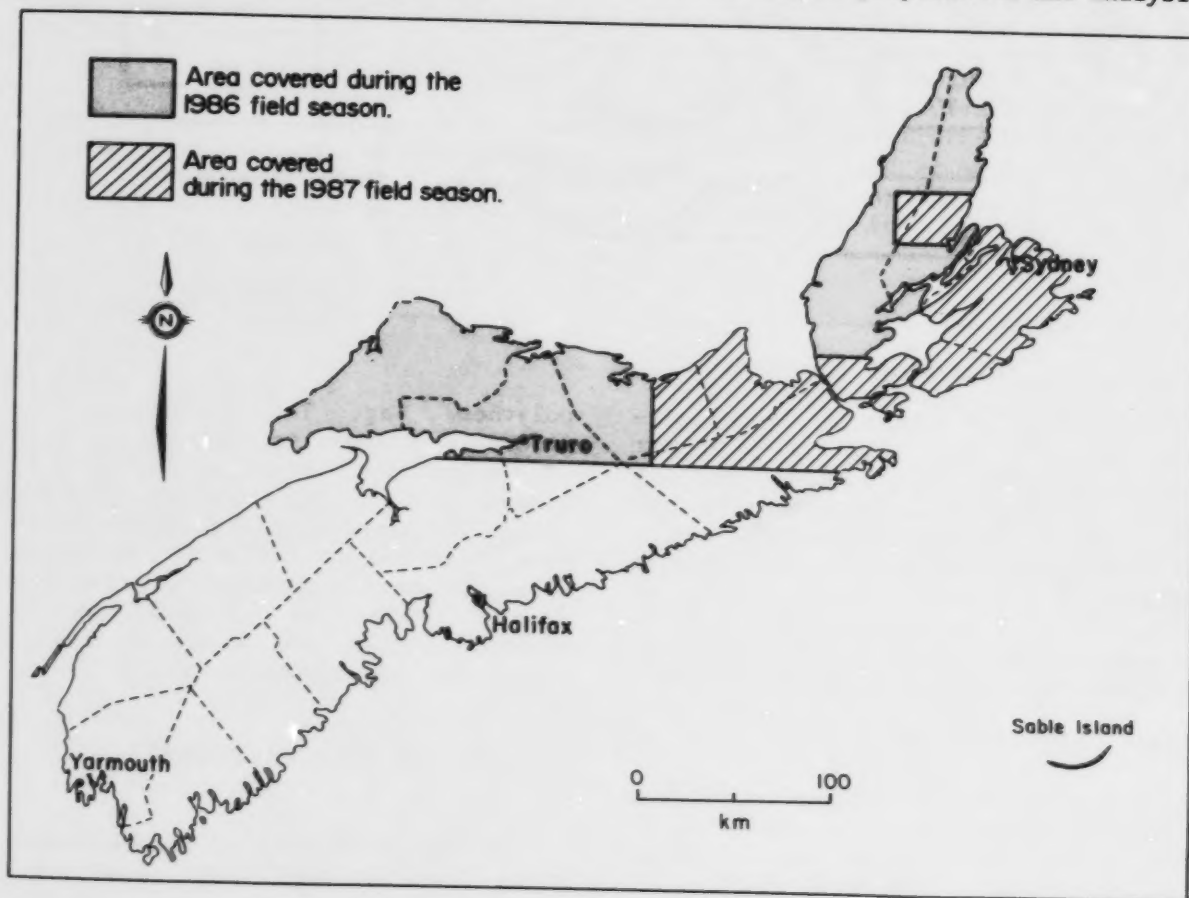


Figure 1. Field areas sampled during 1986 and 1987.

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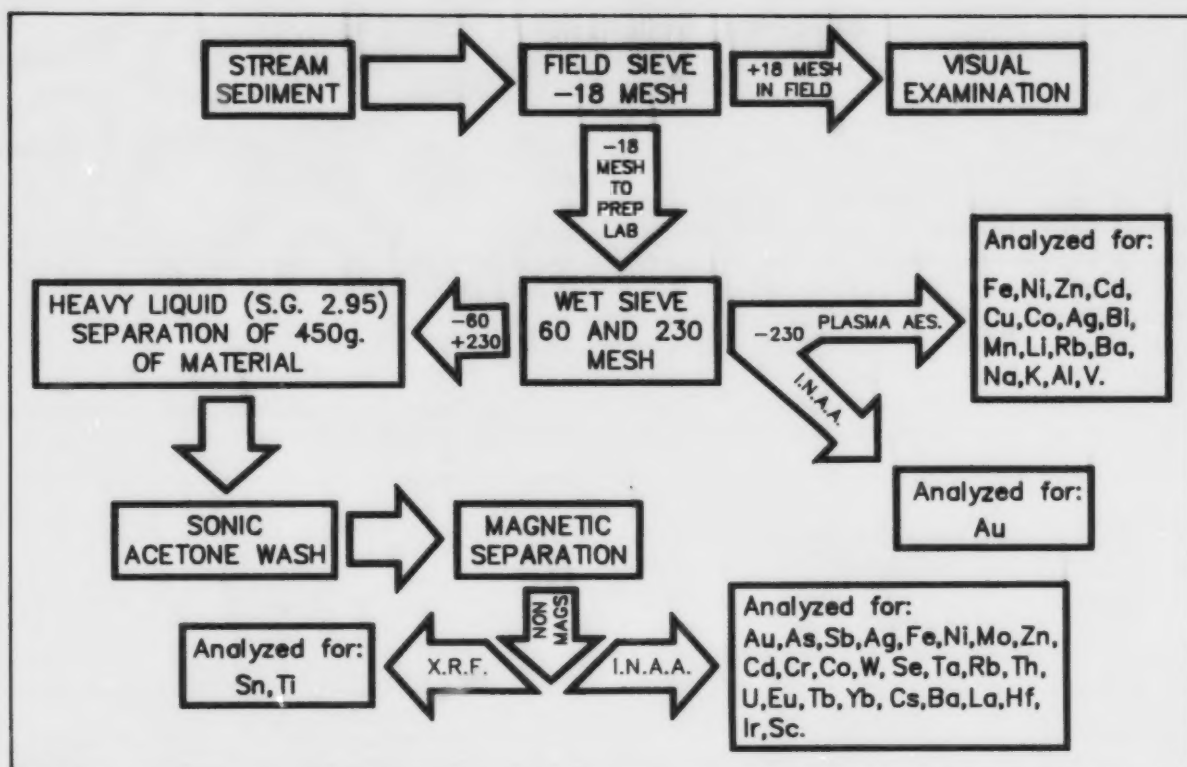


Figure 2. Analytical flow chart.

is presented in Figure 2. To minimize and quantify fine Au loss different size fractions were sampled. The -230 size fraction will be analyzed and compared to results from the -16+230 heavy mineral fraction from each sample (Fig. 2). Stream waters will be analyzed for U by fluorimetry and F by specific ion electrode. Conductivity and pH levels will also be determined.

SAMPLING TECHNIQUE

Samples were collected at optimum trapping sites for heavy minerals in the stream. These sites usually occur behind natural traps such as logs or large boulders or on the inside bank of a meandering stream. The sediment is wet sieved on site to pass through a -18 nylon mesh screen. The sample is collected in a plastic pan along with all of the water used during sieving the sediment. The -18 mesh sample and water are sealed in a 3 ml gauze

polythene bag. The field sampling procedure attempts to minimize the loss of fine Au by preventing any loss of water used during sieving (Boyle, 1979). The samples collected are placed on a table and are not disturbed for at least 48 hours, giving time for any fine Au to settle. Excess water is siphoned out of the bags and samples are packed for transport.

QUALITY CONTROL PROCEDURES

Geological Survey of Canada sample vials are grouped into analytical batches consisting of twenty consecutively numbered samples. In each batch there are two field duplicates to determine field site variation, analytical duplicates, and a standard sample randomly inserted to determine the analytical variation.

SAMPLE PREPARATION PROBLEMS

Erratic neutron activation analysis for Au may result from methods of heavy mineral separation used during sample preparation or from analytical inconsistency at the laboratory. A residue of Br left in samples after tetrabromoethane heavy mineral separation is suspected of producing erratic neutron activation analysis for many elements, including Au. Bromine, which is highly excitable by radiation, may mask the response of other elements to neutron activation, thereby raising their detection limits and destroying analytical precision.

To correct the problem pilot samples treated by tetrabromoethane were washed in an ultrasonic acetone bath. They were then split and sent to different labs for analysis after being

irradiated by epithermal radiation. This investigation should discern any potential analytical incompatibilities.

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FOLLOW-UP GEOCHEMISTRY: PRECIOUS METAL EXPLORATION IN NOVA SCOTIA USING LAKE SEDIMENTS¹

P. J. Rogers

Regional lake sediment geochemistry has indicated new areas of Au potential within the previously disregarded granitoid rocks of the Meguma Zone. Some of these areas have received follow-up geochemical study to investigate the occurrence and nature of anomalous Au values.

Lake sediment geochemistry is best applied to exploration by considering the lake catchment basin as the area of influence for the geochemical sample. The lake bottom sediment, gyttja (the normal sample medium), is fully representative of the geological composition of the lake catchment basin. Gyttja is the end-product of a complex geochemical system and acts as a 'geochemical sink' trapping a mixture of chemical and mechanical weathering components. This characteristic makes gyttja an efficient and cost-effective geochemical exploration indicator for metals, including Au.

Scanning electron microscope (SEM) studies of heavy mineral separates from Meguma Zone lake sediments reveal numerous, discrete, particulate and sometimes exotic mineral phases in gyttja. The mechanical weathering component of lake sediments is seen as an important anomaly-producing agent for Meguma Zone lakes.

A group of three Halifax Peninsula lakes with Au anomalies of up to 60 ppb have an associated heavy mineral suite of predominantly granitic affinity. Identified minerals include apatite,

scheelite, cassiterite, zircon, monazite, ilmenite, rutile and barite. No magnetite or arsenopyrite, indicative of a Meguma Group source for the Au anomalies, were detected. Some of the more exotic heavy mineral phases identified include hoshildite (SnPbO_2), gahnite (ZnAl_2O_3) and as yet unidentified Zn-Fe-Br minerals, possibly alteration products of gahnite.

The occurrence and nature of anomalous Au in organic lake sediments developed on granitic terrain are under investigation. Detailed limnological studies on the three Halifax Peninsula lakes indicate the presence of discrete chemical gradients reflected by distinct faunal changes. The spatial and stratigraphic aspects of the Au anomalies from these lakes have been tested by coring the deeper sub-basins within the Long, Five Islands and Big Hubley Lakes, Halifax County. Detailed chemical analyses of the sediment cores will test the concept of, and potential for, palaeo-placer Au developed in rock flour deposited at the base of lake sedimentary columns immediately after ice retreat. Stratigraphic implications for lake sediment surveys are indicated by the presence of highly anomalous amounts of metals in gyttja due to human activities. This is usually indicated by increases in alumina and other metals in sediment deposited since the settlement of Nova Scotia. Such increases in metal content could produce false anomaly patterns. Chemical analysis of the

¹Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

surface waters entering and leaving the lakes' drainage system will be conducted for major and trace elements. The levels of Au, Sn, W and platinum group elements in surface waters will be quantified using Inductively Coupled Plasma - Mass Spectrometry technology. Recent Au exploration in Nova Scotia has been confined to the area east of Halifax where most known past producers are hosted by Meguma Group sediments. Some Au lake anomalies correlate extremely well to known deposits with anomalous highs, such as Fifteen Mile

Stream which is represented by a high of 853 ppb Au in lake sediment. The regional contoured plot for Au also reveals anomalous areas where no Au mineralization is known. The granitic terrains to the west of Halifax and contact areas of the Musquodoboit and South Mountain Batholiths have unexplained anomalies which require follow-up study. The scale and magnitude of these anomalies indicate that granitoid rocks of the Meguma Zone can be considered potentially mineralized for Au.

REGIONAL TILL GEOCHEMICAL TRENDS IN NORTHERN NOVA SCOTIA¹

R. G. Turner and R. R. Stea

INTRODUCTION

This report is a preliminary compilation of till geochemical data collected under the Quaternary Mapping and Till Geochemistry Program for northern mainland Nova Scotia. The geochemical data will be presented on six 1:100 000 scale open file maps (e. g. Turner and Stea, 1987b; 1987c); detailed work will be included on 1:100 000 scale surficial maps.

During the 1982-86 field seasons 941 till samples were collected from Parrsboro to Canso, an average of about 1 sample per 13 km² (Fig. 1). Pebble

lithology and geochemical data from the till samples were used to: (1) correlate similar till types, (2) determine provenance and (3) prioritize target areas for future exploration by identifying regional geochemical trends.

METHODOLOGY

Analyses were conducted to detect the levels of 14 elements including Ag, Cu, Pb, Zn, Cd, Ni, Co, Fe, Mn, Ca, Mg, As, Mo and U from the clay (< 2 μ m) fraction of the till samples. The fine sand fraction (0.06 - 0.3 mm) heavy mineral separate was analyzed for

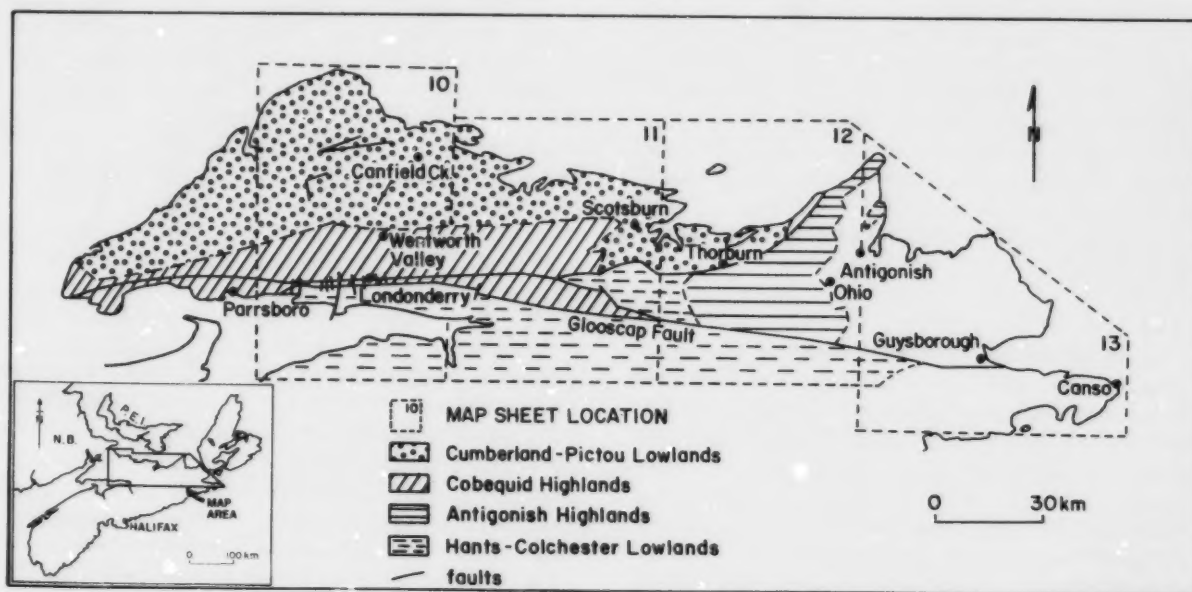


Figure 1. Geological map of northern Nova Scotia showing the map areas covered by the Quaternary Mapping and Till Geochemistry Program.

¹Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

Sn, W and Ba from map sheets 10 and 11 (Fig. 1). All elements were analyzed using Atomic Absorption Spectrophotometry except As and W (colorimetry) and U (fluorometry). Analyses were completed by Bondar-Clegg and Company Limited, Ottawa. Selected heavy mineral samples were examined at the Atlantic Coal Institute to verify anomalies by identifying ore minerals using a scanning electron microscope. About 150 - 200 pebbles (> 4.0 mm) were identified and counted from each sample. The threshold value (95th percentile) for each element was calculated using the cumulative frequency distribution of data from each map sheet (Fig. 1). Anomaly ratios for the elements analyzed were calculated by dividing anomalous analytical values (ppm or %) by the threshold values (Rosenblum, 1980). These data were used to compare anomalous samples on the geochemical maps. The Sn, W and Ba heavy mineral data were weighted using Toverud's (1982) formula (cf. Graves et al., 1987) in order to 'normalize' the amount of heavy minerals in the sample with respect to the total weight of the fine sand fraction used in the heavy liquid separation.

Stea et al. (1986) have shown that significant differences exist among the elemental values of till units defined on the basis of bedrock lithology and grain size. For this regional study, however, all till types, including stony tills and red muddy tills, were grouped together for threshold value calculation. This approach is valid because the interpretation is regional, so variations among till units over the entire study area are minimized. In addition, trace element levels are strongly controlled by lithology variations within a single till unit as well as between till units (Stea et al., 1986). In reconnaissance and detailed surveys (claim block scale) geochemical variations among mapped till units are significant and these

units should be distinguished before geochemical interpretations are made.

Glacial transport parameters described by Salonen (1986) - were defined for selected red muddy tills. General clast dispersal distances were calculated and 2 - 6 km of transport were observed for tills containing 50% of one clast type. The 99th percentile (clasts representing the far travelled component) were transported > 6 km.

Till anomalies were grouped together on the basis of similar suites of anomalous elements. Specific areas containing anomalous elements and associated mineral occurrences are outlined on Figure 2.

GENERAL GEOLOGY

Northern Nova Scotia is physiographically separated into four divisions: the Cobequid Highlands, the Cumberland - Pictou Lowlands, the Hants - Colchester Lowlands and the Antigonish Highlands (Fig. 1). The Cobequid Highlands consist of Helikian to Devonian - Carboniferous rocks segregated into numerous fault blocks and separated from the lowlands by the Glooscap Fault System (Donohoe and Wallace, 1982). The Cumberland - Pictou Lowlands are underlain predominately by Upper Carboniferous sedimentary rocks. The Hants-Colchester Lowlands are mainly composed of Carboniferous Horton and Windsor Group clastic and evaporitic rocks and Triassic clastic rocks. The Antigonish Highlands are composed predominantly of Precambrian metavolcanics and metasediments unconformably overlain by Lower Paleozoic strata (Murphy, 1984). East of the Antigonish Highlands Devonian-Carboniferous sedimentary rocks predominate.

TILL ANOMALIES COINCIDENT WITH KNOWN MINERAL OCCURRENCES

The till anomaly association map shows distinct geochemical trends, some

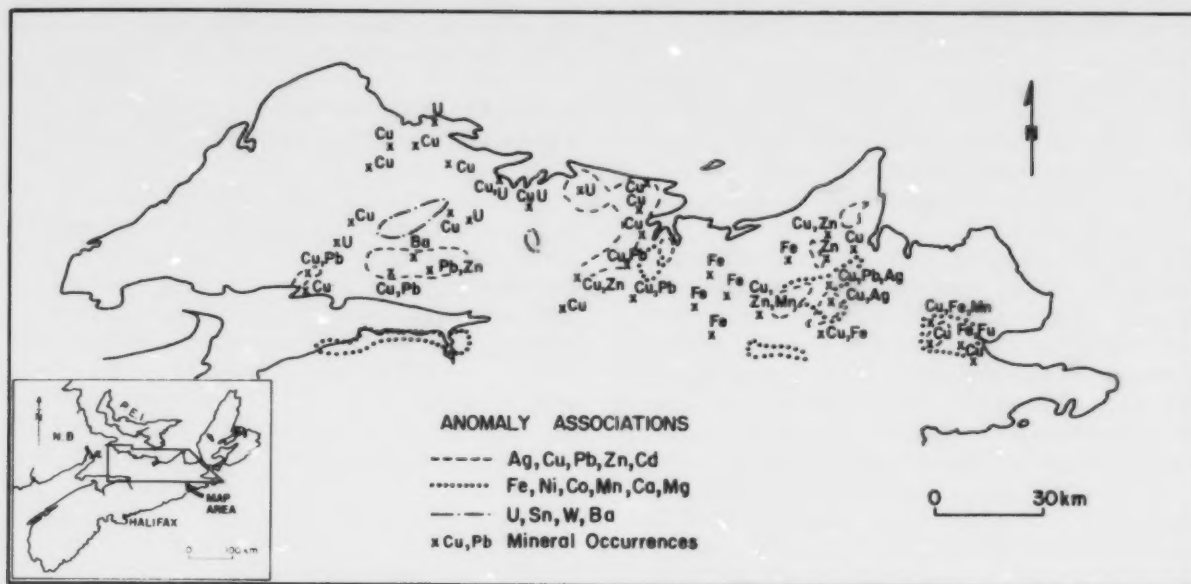


Figure 2. Till anomaly associations and mineral occurrences in northern Nova Scotia.

of which are spatially related to known faults, bedrock units and contacts, mineralized bedrock and (or) known deposits (Figs. 1 and 2). Cu anomalies in till over the basinal areas are related to the nearby Windsor Group carbonates. Mg-Ni-Co-Mn-Cu associations in the Cobequid and Antigonish Highlands are related to comminution and weathering of igneous clasts rich in ferromagnesian minerals (Stea et al., 1986). Elevated Fe levels are associated with the stony till sheet on the Cobequid Highlands.

Red muddy till anomalous in Cd-Zn-Pb-Cu is located to the north and northeast of the Canfield Creek Cu deposit. This Cu prospect (Fig. 1) occurs at the contact between the red and grey sandstones of the Pictou Group and contains 300,000 tons of 1.2% Cu (Sullivan, 1981). Pb-Zn-Cd anomalies may be associated with this deposit.

An area of Cu-Pb and Fe-Ni-Co till anomalies is coincident with fault

related stratabound and (or) stratiform Fe-Cu-Ag and Pb-Zn bedrock mineralization north of Londonderry (Chatterjee, 1983). Barite mineral occurrences are also present in this area. Scanning electron microscope (SEM) work revealed that a heavy mineral separate from a nearby till sample contained 15% barite and 1.6% witherite. A single chromite crystal was also observed during SEM examination of a till sample from this area.

Till covering the Scotsburn Anticline contains many Cu-Pb-Zn-Cd anomalies. A defined zone of Ag anomalies in this till overlies the Boss Point Formation. Stratiform Cu-Ag occurrences are present at the contact of the Boss Point Formation sediments and the Pictou Group sandstones. A Cu occurrence is present at the contact between Boss Point Formation sediments and Millville Formation conglomerate (Chatterjee, 1983). Locally, minor galena and oxidized Zn mineralization occurs primarily in the calcareous

pebble conglomerate facies of the Boss Point Formation (McCulloch, 1984).

The Devono-Carboniferous strata west of Guysborough are locally mineralized with chalcopyrite, galena and specular hematite. Previous till, stream and lake regional geochemical surveys located anomalies of Cu, Ni, Pb, Zn, Co, Fe, Mn, Mg and As (Stea and Fowler, 1979; Boyle et al., 1962; Rogers and MacDonald, 1984; Richardson and Bingley, 1979). These multi-element anomalies are spatially associated with the known mineral occurrences. Till samples near Guysborough contain many Ni-Co-Fe-Mg and Cu-Pb-Zn-Ag anomalies. Turner and Stea (1987a) show a strong association between Cu, Ni, Co, Mn and Mg. Lead, Zn and Co form a separate association of positively correlated elements. The presence of Zn anomalies suggests this metal may be associated with the Cu and (or) Pb deposits and is not yet identified, or it may form a separate occurrence.

TILL ANOMALIES IDENTIFYING POTENTIAL MINERALIZATION

An area of Sn-W till anomalies occurs overlying and to the north of a Cambrian granite near Wentworth. Weathered cassiterite grains were observed in heavy mineral concentrates from three till samples collected near the contact of this granite with the Byers Brook Formation. Chatterjee (personal communication) observed cassiterite in drill core from mafic volcanics of the Byers Brook Formation. Rogers (personal communication) has identified cassiterite in streams draining this area.

Many stratiform Cu-Pb-Zn and Ag mineral occurrences are located along the unconformity separating the Windsor Group carbonates and metavolcanic rocks near Antigonish. Although one Ag anomaly near Ohio is coincident with a known Cu-Ag mineral occurrence, other Cu-Pb-Zn-Ag till anomalies are present

to the south and southwest of the known mineral showings and may identify new mineral occurrences (Figs. 1 and 2).

MINERAL OCCURRENCES WITHOUT ASSOCIATED TILL ANOMALIES

Many small Cu occurrences are associated with organic - rich grey beds within a predominantly red sedimentary sequence in the northern lowland regions. Cu is depleted in the Pictou Group redbeds and the overlying till. This may be due to the mobilization of Cu during diagenetic groundwater alteration and reddening of the bedrock (Stea et al., 1986). The mobilized Cu is precipitated at solution fronts along the red - grey sandstone contact (Stea et al., 1986).

Iron occurrences are present in the sedimentary rocks south of Thorburn, however there are no coincident till anomalies in this area.

CONCLUSIONS

The element association grouping method is useful in a regional till survey for localizing target areas with many 'multi - element' anomalies for future exploration. Target areas identified using till geochemistry include (1) fault related Cu-Pb-Zn-Ba near Londonderry, (2) Sn-W near the Cambrian granites in the Wentworth area, (3) Cu-Pb-Zn-Cd in the Pictou Group sediments north of Canfield Creek, (4) Cu-Ag and Pb-Zn mineralization along bedrock contacts of the Scotsburn Anticline, (5) Cu-Pb-Zn and Ag in the metavolcanics west of Ohio and (6) Cu-Fe and possibly Zn in the Devono - Carboniferous sedimentary rocks near Guysborough.

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ESKERS OF NOVA SCOTIA¹

Y. Brown and R. R. Stea

INTRODUCTION

Preparation of a surficial geology map of Nova Scotia is one project being addressed by the Quaternary Mapping and Till Geochemistry Program under the Canada - Nova Scotia Mineral Development Agreement. To date, the majority of eskers and many drumlins, moraines, kettles and structural ridges on the mainland have been compiled and plotted on a base map (1:250 000) of the Province using published maps by MacNeill (1956), Hickox (1962), Stea and Fowler (1979, 1981), Stea (1982), Stea and Grant (1982) and Stea et al. (1986); and unpublished material of Stea. Glacial striations and other glaciogene landforms will also be on the completed map which will include Cape Breton Island. Glaciological implications of the eskers that have been compiled to date are discussed in this report.

Eskers are long, sinuous ridges chiefly composed of sand and gravel, and locally silt and boulders. The sediments are deposited by meltwater streams in ice tunnels within or at the base of a glacier and remain as ridge-like deposits when the ice recedes. Cross-stratification of sediments within the esker indicates the paleocurrent direction of the stream (Flint, 1971). Eskers generally form during the terminal stages of glaciation (Shreve, 1985a) and the trends of the ridges parallel the direction of ice flow (Flint, 1971). Former ice-surface profiles can be reconstructed mathematically using

deviations in the paths of eskers and transitions in esker types (sharp-, multiple- and broad-crested; Shreve, 1985b).

ESKERS IN NOVA SCOTIA

Figure 1 is a map of the major eskers on mainland Nova Scotia. In the southwestern part of the Province two general orientations of eskers are apparent: north-south and east-west. Eskers near Yarmouth were studied by Sinclair (1978). Including gaps, the two major eskers in Sinclair's study area extend for 12 and 8 km and roughly parallel the Tusket and Chebogue Rivers, respectively. The eskers are made up of mounds, termed nodes, with intervening lower areas, termed internodes. They are capped by till and consist of sediments ranging in size from silt to boulder. The esker material represents local bedrock; transport distance of the coarser clasts is less than 12 km. A subglacial tunnel model of formation and southward ice flow is favoured by Sinclair (1978). A southwest ice flow trend is indicated by Annapolis Valley eskers but paleocurrent directions are unknown.

Most of the eskers in western Cumberland County, on the Chignecto Peninsula, have southward paleocurrent indicators (Stea et al., 1986). Boars Back Ridge, a discontinuous esker which parallels the west side of River Hebert in Cumberland County was most recently studied by Wightman (1980). The esker extends for about 20 km, ranges in

¹Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

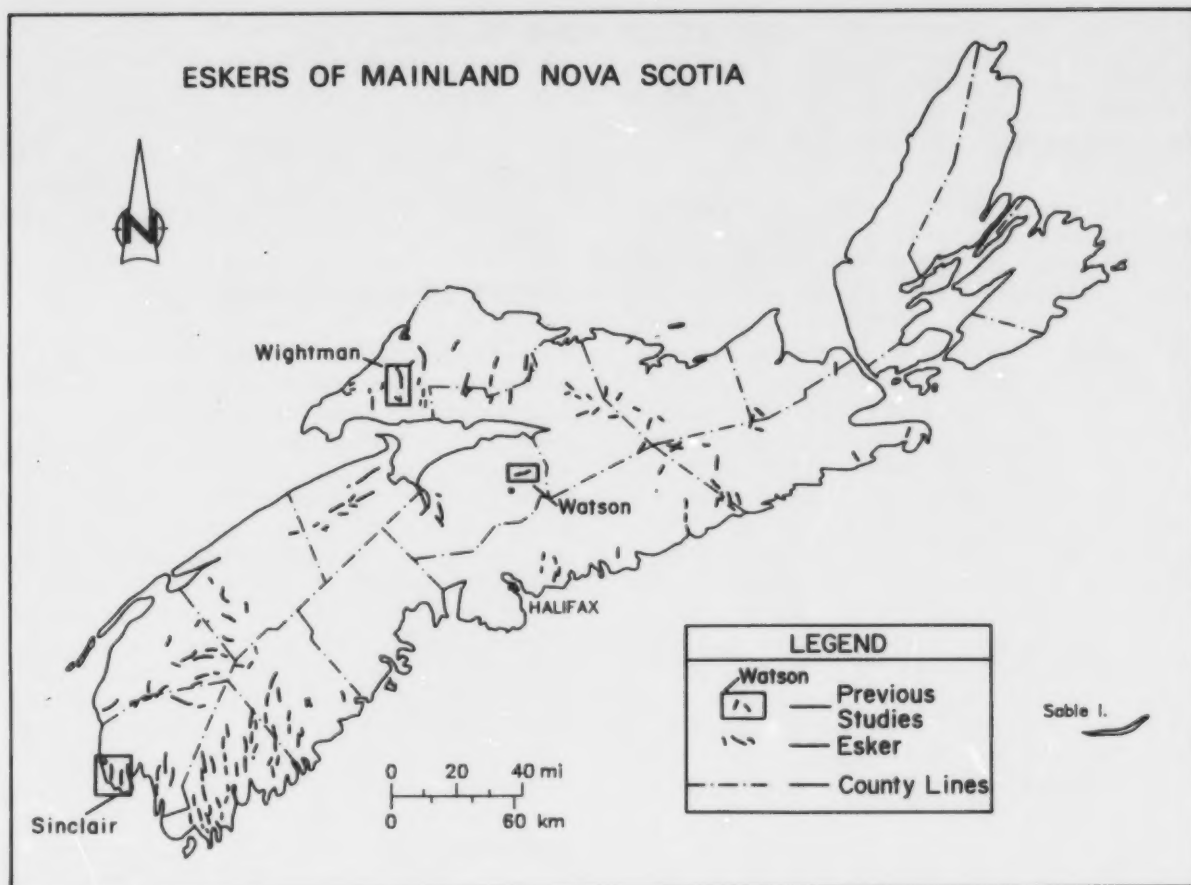


Figure 1. Eskers of mainland Nova Scotia.

height from 3-6 m and is about 20 m wide. Cross-stratification in the esker dips mainly to the south but also to the east and north. The most common pebbles in the ridge are sedimentary rocks, probably derived from the underlying Carboniferous units. In the remainder of Cumberland County the eskers trend south with one esker indicating a northward paleocurrent direction.

Eskers trend south in western Hants County near the Avon River, whereas those in the eastern part of the county trend west. A 25 km long ridge east of Upper Nine Mile River was studied by Watson (1984). Six sediment types, ranging from silt and clay to coarse gravel, were defined and occur

in beds which are thickest in the ridge core and thin toward the flanks. Watson concluded that the sections studied represented esker beads deposited from the mouth of a subglacial tunnel and that westward ice flow was responsible for the deposition.

The majority of eskers in the northern counties of Colchester, Pictou and Antigonish indicate a southwestward paleoflow whereas those along the eastern shore of the Province have southward paleocurrent indicators (Stea and Fowler, 1979). An indication of southwestward flow is noted in an esker near Canso in eastern Guysborough County.

CONCLUSIONS

The trends and directions of the eskers on mainland Nova Scotia (Fig. 2a) support the directions of the four ice flow phases (Fig. 2b) postulated by

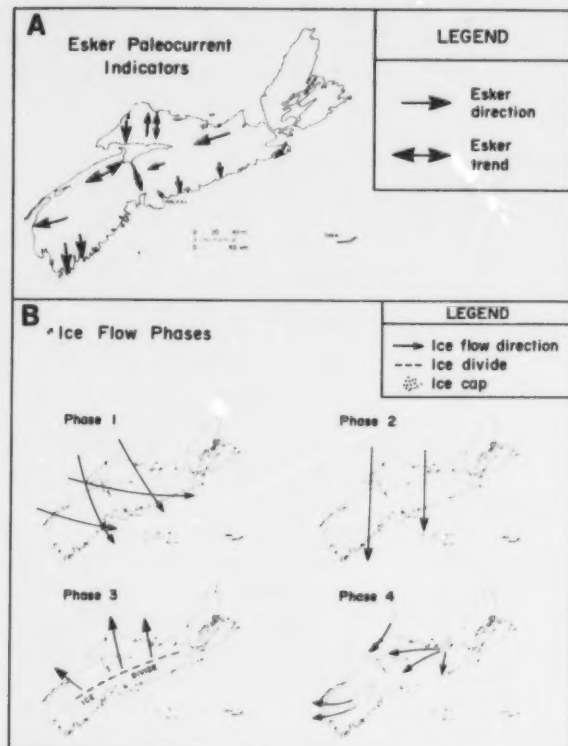


Figure 2. (a) General paleocurrent trends and directions indicated by eskers in Nova Scotia. (b) Simplified diagram of ice flow phases in Nova Scotia (Stea et al., 1987).

Stea et al. (1987). Eastward- then southeastward-flowing ice moved across the Province (phase 1) and was followed by a southward flow (phase 2). Ice then moved northward across the northern half of Nova Scotia from a central ice divide (phase 3). Local ice caps formed on Prince Edward Island, the South Mountain and the Antigonish Highlands and from these areas ice flowed westward and southwestward (phase 4).

Comparison of paleocurrent indicators from the eskers and the proposed ice flow directions allows speculation on the probable formation of the eskers by the four ice flow phases. Phase 1 may have influenced the formation of some of the eskers in southern Nova Scotia which have southward paleocurrent indicators, although phase 2 likely played a more significant role. The eskers in Cumberland County and those along the eastern shore of the Province are also probably the result of southward flow during phase 2. The northward ice flow of phase 3 was likely responsible for the formation of the esker in eastern Cumberland County which has northward paleocurrent indicators. The west- and southwest-trending eskers of Hants, Colchester, Pictou, Antigonish and Guysborough Counties, the Annapolis Valley and southwestern Nova Scotia were probably formed by late phase 4 ice flow. The esker at Canso may have been the result of flow from an offshore ice cap.

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EDUCATION AND PUBLIC AWARENESS¹

H. V. Donohoe and M. E. Devanney

The purpose of the Education and Public Awareness Program (EPAP) of the Mines and Minerals Branch is to disseminate information about the geology, mineral resources and mining history of the Province. The Public Information Program of the Canada-Nova Scotia Mineral Development Agreement (CNSMDA) and the EPAP share the objectives of building a broader understanding of mineral commodities, mining exploration, geology and mineral resources in Nova Scotia and of the government's role in promoting and managing them. These objectives are achieved through the publication of informative booklets, brochures and newsletters, travelling displays, a mining kit for schools, a very popular series of guided walks, and the preparation and display of audio-visual packages.

A series of general information circulars now available include *Nova Scotia Gold, Minerals and Mining in Nova Scotia* and *Geology of the Halifax-Dartmouth Area*. Pamphlets dealing with the rights of landowners and prospectors include *Mineral Rights, Landowners and Mineral Exploration and Staking Claims in Nova Scotia*. The *Directory of Goods and Services for Exploration Companies* provides a convenient reference to companies serving Nova Scotia's exploration industry. Several longer publications near the printing stage are *Gold in Nova Scotia* and *The Rock and Mineral Collecting Guide to Nova Scotia*.

The geological walking tours developed over the past two years have proven very successful. Approximately 400 people have attended the walks to date, an average of 25 per walk. Visitors as well as local residents, both young and old, participate in the walks in order to learn about the geology around them. There are two building stone walks in the Halifax metro area: one in the downtown core and the other along Spring Garden Road. These walks highlight the building stones and their constituent minerals, as well as providing insight into the historical development of the Province's building stone industry. The guided walks at Point Pleasant Park and Peggys Cove emphasize how local rocks and landforms have influenced the settlement of the area. These projects were initiated by the Department in co-operation with the Nova Scotia Museum. A geology walk produced for Victoria Park in Truro was developed in conjunction with the Truro Parks and Recreation Commission as part of the Park's centennial celebrations.

This summer the EPAP maintained a busy display schedule, erecting displays in 17 locations throughout the Province (Table 1). These included a number of mall exhibits where displays could be introduced to a representative section of the general public. In addition, the collaborative efforts of the Department and Energy, Mines and Resources Canada (EMR) initiated two one-week-long display tours to

¹Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

Table 1. Summer display schedule, 1987.

Dates	Location	Event
June 12, 13, 14	Windsor	Nova Scotia Forestry Exhibition
June 25, 26	Halifax	Halifax Shopping Centre display
July 9, 10	Yarmouth	K-Mart Plaza display
July 16, 17	Dartmouth	Mic Mac Mall display
July 23, 24	Amherst	Amherst Centre display
July 28-31		NSDME-EMR DISPLAY TOUR 1
28	New Minas	Towers Mall display
29	Digby	Evangeline Mall display
30	Kejimikujik	National Park display
31	Bridgewater	Bridgewater Mall display
August 7, 8, 9	Parrsboro	Rockhound Roundup
August 17-21		NSDME-EMR DISPLAY TOUR 2
17	Port Hawkesbury	Port Hawkesbury Shopping Centre display
18	Sydney	Mayflower Mall display
19	Sydney	Sydney Shopping Centre display
20	Antigonish	Antigonish Shopping Centre display
21	New Glasgow	Aberdeen Mall display
August 27, 28	Truro	K-Mart Mall display
September 12, 13	Waverley	Waverley Gold Rush Days

communities in different areas of the Province.

The typical display format highlights the geology and mineral industry of Nova Scotia, as well as programs and activities related to the CNSMDA. Local rocks and minerals of interest and economic importance are an integral part of the exhibit. Many of the popular rock and mineral samples given away at the displays are donated by local companies.

Displays often include material of local interest. This year the display took on a more interactive role with the addition of an electronic Mining Quiz. A slide show entitled *The*

Mineral Industry of Nova Scotia, produced by EMR with technical advice from the members of EPAP, attracted a great deal of interest, as did the mining quiz.

This year The Mining Kit, developed co-operatively by NSDME and the Nova Scotia Museum, will be field tested by selected teachers in the Province. The Kit includes samples of rocks and minerals of economic importance, slides, videos and an information package including brochures, posters, pictures and a Teachers' Resource Guide. The teachers' guide provides appropriate background material, suggested teaching strategies, activities and experiments.

Two 'rock videos' have been produced, each representing a different commodity, mining method and geographical region of the Province. *Salt of the Earth* examines the world of underground mining at Pugwash, Cumberland County, and describes the salt mining industry in Nova Scotia. The open pit tin mine in Yarmouth County is the subject of the video *Real Tin*. These videos introduce the viewers to modern day mining techniques, equipment and jobs. The Kit is designed to meet the requirements of the optional Grade 8 teaching unit *Science in Mining* but will also be available for use by students at other levels.

The consultation and advice offered through EPAP aided in completion of the video *The Mineral*

Wealth of Atlantic Canada. This video is an EMR sponsored project and is one of four being developed by the Atlantic Geoscience Society. The other videos in the series are *The Appalachian Story*, *The Recent Ice Age* and *Fossil Fuels of Atlantic Canada*.

With the support of the Public Information Program of the CNSMDA, projects are planned to prepare filmstrip presentations outlining the geology, mining and mineral resources of the Province, a continuing photographic record of exploration and mining developments, photographic packages related to the mining history of the Province, prospecting courses, and newsletters. The intent of these projects is to familiarize the general public with geology and mining in Nova Scotia.

ACADIA UNIVERSITY DEPARTMENT OF GEOLOGY RESEARCH

J. A. Colwell¹

Acadia University is located at Wolfville, Nova Scotia, in the eastern Annapolis Valley about 100 km northwest of Halifax. The Department of Geology consists of 7 full-time professors, 2 part-time lecturers and 1 demonstrator. In addition, Drs. Stewart A. Ferguson and Alan S. Macdonald were appointed honorary research associates this year. There are 47 undergraduate majors and 13 graduate students.

The Department of Geology emphasizes an integrated field and laboratory approach and offers instruction and research training leading to the Bachelor of Science, Bachelor of Science with Honours, and Master of Science degrees. The undergraduate degree programs have been revised and are now 4-year degrees. Research funding comes from mainly faculty grants and contracts which are held by most of our staff. All the full-time graduate students also hold fellowships.

Research conducted by the faculty and students is diversified. However, the main thrust is Nova Scotia geology with various projects involving economic geology, igneous petrology, metamorphic petrology, geochemistry, biostratigraphy, paleontology, sedimentology, ichnology, structural geology, regional geology and basin analysis.

RESEARCH PROJECTS

S. M. Barr: continued regional mapping programs in Cape Breton Island

and southern New Brunswick; related petrologic studies emphasize granitoid and volcanic units.

B. W. Cameron: barrier island development; lithostratigraphy and age of the Scots Bay and Blomidon Formations based on conchostracans, trace fossils and silicified snails, ostracodes and fossil fresh water algae.

J. A. Colwell: mineral deposits; clay mineralogy; geology of the North Mountain basalt; zeolites.

R. G. Moore: biostratigraphy of the Windsor Group; geologic mapping in the Mosherville, Rawdon and Clarksville areas.

R. P. Raeside: regional mapping of the Cape Breton Highlands; metamorphism of Meguma Group of southwest Nova Scotia.

G. R. Stevens: structural geology of southwest Nova Scotia; rock fabric; remote sensing and computer graphics.

N. A. Van Wagoner: physical volcanology of the Fourchu Group, Cape Breton Island setting.

M.Sc. THESES IN PROGRESS

L. Daigle: Sedimentology of the Lower Stellarton Units, Pictou County, Nova Scotia.

F. Dennis: The Deep Cove granite and associated Cu-Mo-Ag-Bi mineralization,

¹ Head, Department of Geology, Acadia University, Wolfville, Nova Scotia

southeastern Cape Breton Island.

M. Justino: Geology of the Marble Mountain area, Cape Breton Island.

R. Snow: Sedimentology and depositional environments of the Thorburn Member of the Stellarton Group in Nova Scotia.

W. Yaowanoyothin: Petrology of the Black Brook plutonic Suite and associated gneisses, Cape Breton Highlands.

A. Deal: Carboniferous geology, Cumberland County, Nova Scotia.

E. Mutunga: Seismic stratigraphy of part of the Scotian Slope.

J. Campbell: Stratigraphy, metamorphism, deformation and age of the George River Group, Creignish Hills, Cape Breton Island.

B.Sc. THESES IN PROGRESS

G. Walker: Geochemistry of diopside from calc-silicates in Cape Breton Island.

S. Deveau: Geology and petrogenesis of the Grenvillian Lowland Cove Syenite, Cape Breton Island.

A. Armitage: Geology of Whycocomagh Mountain.

ST. FRANCIS XAVIER UNIVERSITY DEPARTMENT OF GEOLOGY

GENERAL

St. Francis Xavier University is located in Antigonish, about 250 km east of Halifax. The geology department consists of 4 staff members and approximately 30 undergraduate students.

The geology program is designed to provide a strong fundamental background for students who continue on to graduate study and at the same time enough operational practical training to equip those who are immediately employed as professional geologists.

The geology curriculum of the department reflects this aim. Courses such as Mineralogy, Crystallography, Petrology, Stratigraphy and Sedimentation, and Structural Geology are specialized and basic. Applied courses include Ore Deposits, Petroleum Geology, Coal Geology, Geophysics and Geochemistry. The latter provide an opportunity to use and to elaborate on the basic principles encountered in earlier geology courses and courses obtained outside this department, especially physics, chemistry and mathematics. There is a seminar course for senior students that is directed to developing the students' capacity to formulate a problem, devise a plan of attack, execute the plan and report the results orally and in written form. Figure 1 illustrates how the various courses are interwoven to form a coherent whole.

LABORATORY STUDIES

The field is viewed as the most important means of laboratory instruction. To bring together textbook and actual occurrence, certain laboratory periods are devoted to

examination in the field. As expected, this is subject to seasonal restrictions.

In a number of branches of earth science, 3-dimensional visualization is extremely important. In Mineralogy, training in 3-dimensional visualization is promoted by the use of crystal models, lattice models and the examination of minerals in their actual crystalline form. In Structural Geology, 3-dimensional training is continued through the use of descriptive geometry and stereographic projection.

Other aspects of laboratory work include the examination of thin sections under the petrographic microscope, analyses of structures on maps and geochemical analyses including work on radiometric dating of rocks.

FIELD CAMP AND SUMMER EMPLOYMENT

At the end of the sophomore year all students are strongly urged to attend the 10-day spring field camp held annually at St. Francis Xavier University. The camp forms the core of a Field Methods course which also involves numerous mapping projects during sophomore, junior and senior years.

In addition, many geology students obtain employment in geological work during the summer. This is regarded as an effective extension of their classroom and laboratory experience.

FACULTY

Here is a brief outline of the geology staff at St. Francis Xavier University:

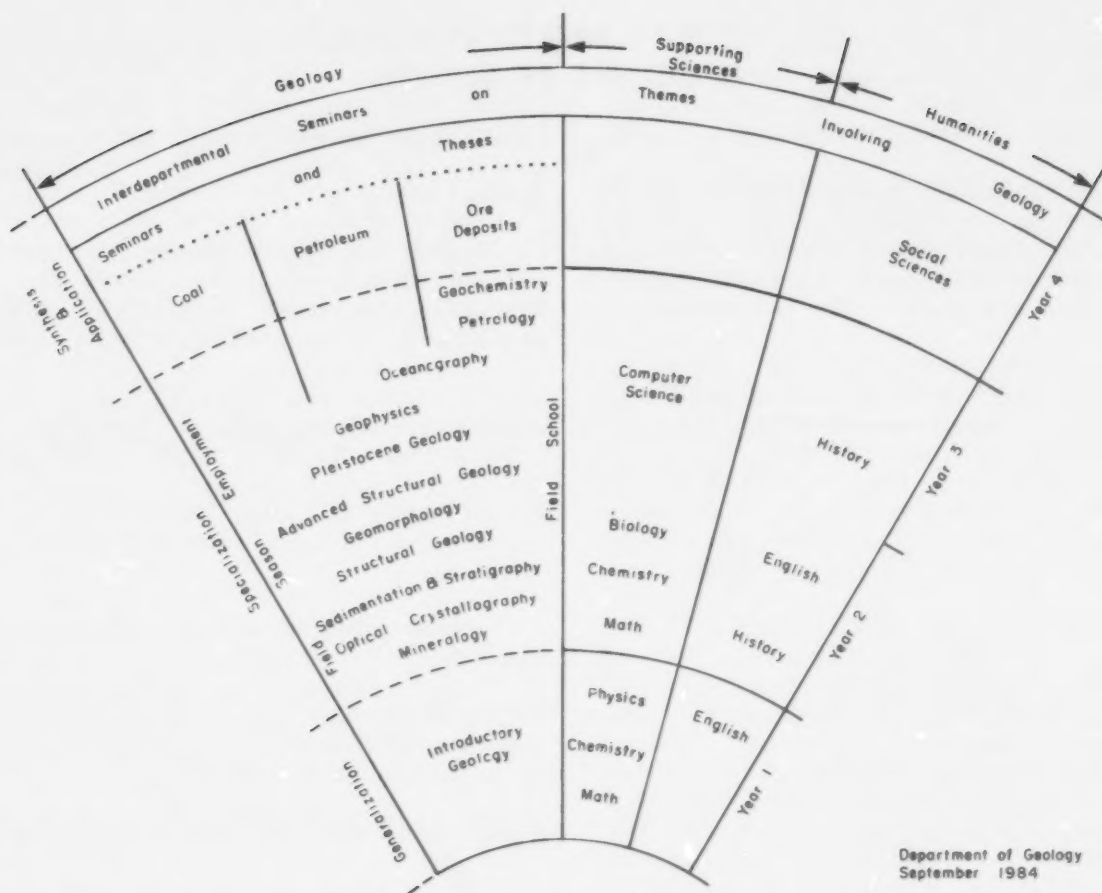


Figure 1. Interrelationship of courses at Saint Francis Xavier University

R. F. Cormier, Ph.D. (M.I.T.), has taught at St. Francis Xavier University for 30 years. He teaches introductory geology, geochemistry and historical geology. The age determination of rocks, using the ratio of radioactive rubidium to strontium, is his major research activity.

William S. Shaw, Ph.D. (M.I.T.), is Chairman of the department and teaches oil and gas geology, coal geology, stratigraphy and geophysics. He came to St. Francis Xavier University after a long career in oil exploration. Oil, coal, salt and ore deposits are his chief research interests.

J. Brendan Murphy, Ph.D. (McGill), teaches courses concerning the origin

of igneous and metamorphic rocks, introductory and regional structural geology, optical mineralogy and tectonics. His research interests at present concern the geological evolution of the Antigonish and Cobequid Highland areas and the evaluation of its mineral potential.

Cynthia Murphy, M.Sc. (McGill), teaches mineralogy and is responsible for computer applications in geology. Her current interest is the geology of the Gaspé Peninsula in Quebec where she is studying the magmatic history of granitic and volcanic rocks.

SAINT MARYS UNIVERSITY DEPARTMENT OF GEOLOGY

The Geology Department of Saint Marys University offers a complete undergraduate program leading to geology major and honours degrees. Within the department, courses are offered in most geological disciplines supplemented by cross-listed courses such as geomorphology which are given by other departments. The average enrollment in our program is about 30 geology majors and 7 honours students. The relatively small size of the department enables us to maintain a high level of student-faculty interaction. Our aim is to give the students a well-rounded background in geology which will enable them to either continue their studies at the graduate level or immediately enter the industry.

The department is mainly housed on 2 floors of the Science Building and facilities consist of classrooms, labs for photomicroscopy, thin section and sample preparation, geochemistry, micropaleontology, sedimentology, a darkroom, a drafting room, offices and a student lounge, as well as additional storage space and a rock crushing room in the basement. Students also have access to the university VAX-11 computer. In 1983, the department was awarded funding to establish a regional X-ray fluorescence centre for the analysis of major and trace elements in geological samples. With this equipment added to our newly-updated neutron activation lab and other facilities, the department has been able to attract visiting researchers from different parts of the world.

The research focus within the department has been on the geochemistry and petrology of igneous rocks from Atlantic Canada as well as from other regions such as the eastern Mediterranean, France, South America,

the Pacific Islands and Africa. Additional projects are investigating the stratigraphy and sedimentology of the Cambro-Ordovician Meguma Group of Nova Scotia, the structure and sediments of continental margin sequences in the Newfoundland Appalachians, the geothermobarometry and uplift history of polymetamorphic terranes, and Early Tertiary Ostracoda from Asia and Late Cenozoic ones from the Beaufort Sea.

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NOVA SCOTIA COLLEGE OF GEOGRAPHIC SCIENCES: REMOTE SENSING RESEARCH IN SOUTH MOUNTAIN BATHOLITH

M. S. Akavi¹

INTRODUCTION

Three co-operative projects were conducted under the author's supervision at the College of Geographic Sciences (COGS) during the 1986-87 academic year. The area is in the eastern portion of South Mountain Batholith bounded by Halifax Harbour and Highway No. 10. A complete Landsat Thematic Mapper (TM) dataset exists for the study area. The data possess high quality spacial resolution of 30 m and 6 spectral bands being acquired on September 30, 1985. Digital Landsat TM data, and conventional geologic and radiometric maps were integrated in a database utilizing remote sensing and geographic information systems.

The authors and titles of these projects are as follows:

1. Ross A. Bishop
The application of remote sensing techniques for geologic mapping and exploration in the East Dalhousie area of the South Mountain Batholith, Nova Scotia.
2. Robert E. MacDougal
Geologic mapping and mineral exploration of the South Mountain Batholith: New Ross area.
3. Scott M. Shupe
Reconnaissance mineral exploration and lineament mapping in the South Mountain Batholith near Halifax, Nova Scotia using Landsat Thematic

Mapper and airborne radiometric data.

OBJECTIVES

The main objectives of these investigations are:

1. to synthesize a multilayer database comprising geologic map data, airborne radiometric data, and Landsat imagery;
2. to document and evaluate the methodology used for the construction of such a geocoded database, and
3. to evaluate the utility of this database for geological investigation and the detection of target areas of potential economic mineralization.

METHODOLOGY

The titles of these projects indicate that they are slightly different in scope and style. However, the rationale and procedures set forth in these investigations could be summarized as follows:

1. digitizing of geological boundaries and conventional radiometric data,
2. enhancement of satellite data for geological investigations,

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3. transfer and superimposition of the above data utilizing the ARC/INFO Geographic Information System and the ARIES II Image Analysis System,
4. visual examination and analysis of the above data to detect geological/geophysical anomalies or associations,
5. preparation of geological maps and reports indicating possible target areas of mineralization, and
6. execution of field work to examine and verify the interpretive remote sensing investigations.

RESULTS

The authors would like to encourage the reader to review the original copy of the students reports submitted as open file reports to the library of the Nova Scotia Department of Mines and Energy. These reports include interpretive geological maps depicting possible exploration target areas as well as a number of Landsat imagery and other illustrations. A brief highlight of the results to date follows:

1. generation of a geocoded database allows interchangeable and interactive display and examination of all data;
2. visual examination of map data, Landsat imagery, and radioelement distributions indicate that spectral and textural characteristics may serve to discriminate plutonic rocks from adjacent metasedimentary rocks;
3. lineaments and other geological structures can be detected;
4. distribution and coalescence of above-threshold radiometric values are important in the detection of bedrock lithology;
5. the database can be utilized to target exploration areas on the basis of the relationship between radiometric distribution, structural deformation, and mineral emplacement.

Your participation in co-operative projects pertaining to the specific needs of your organization is welcomed. Also, prospective employers may contact the graduates through the COGS.

MINERAL TECHNOLOGY AT THE UNIVERSITY COLLEGE OF CAPE BRETON: A CO-OP EDUCATION PROGRAM

H. R. Oldale¹

Commencing September 1987, Mineral Technology at the University College of Cape Breton will become a 3-year co-operative education program. It will include 5 academic semesters and 3 four-month job placements leading to a diploma in Mineral Technology (Table 1). The program trains students in applied applications of geology,

mineral exploration, surface and underground mining, mineral processing, and analytical chemical methods. Further information may be obtained by contacting the Co-operative Education Office (902) 539-5300 ext. 129, 374, or the Mineral Technology Department (902) 539-5300 ext. 191, 194.

Table 1. Curriculum outline for the Mineralogy Technology program

SEPT - DEC	JAN - APR	MAY - AUG
Year 1		
Academic Term 1	Academic Term 2	Work Team 1
Math I	Math II	
Physics I	Physics II	
Communications I	Communications II	
Chemistry I	Chemistry II	
Geology I	Geology II	
Surveying I	Mining I	
	Comp. Program & Applic.	
Year 2		
Academic Term 3	Work Team 2	Academic Team 4
Math III		Math IV
Geology III		Exp. Methods II
Mining II		Surveying II
Exp. Methods I		Assaying I
Min. Process I		Min. Process II
Drafting I		Drafting II

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Table 1. continued

Year 3

Work Term 3

Academic Term 5

Math V

Geology IV

Assaying II

Mining III

Exp. Methods III

Mining Projects

DISCOVERY OF FOSSILS AND MEANDERING STREAM DEPOSITS IN THE LATE TRIASSIC BLOMIDON FORMATION OF NOVA SCOTIA

B. Cameron and J. R. Jones

INTRODUCTION

The Blomidon Formation (Fundy Group) has long been regarded as virtually devoid of invertebrate fossils, and its depositional environments have been interpreted usually as lacustrine or playa. However, recent field studies have indicated that invertebrate fossils and fluvial features are more common than once thought.

FOSSILS

Until Klein (1962) found a poorly preserved conchostracan (bivalved freshwater crustacean) at Delhaven (Fig. 1), conchostracans were only known from a local till boulder

(Powers, 1916). Recently, the authors found 2 kinds of conchostracans with numerous lines and smooth-shelled ostracodes from 4 coastal exposures, 1 near Digby and 3 near Blomidon (localities 1, 3, 4, and 5 of Fig. 1). Scanning electron microscopy indicates that the ostracodes are freshwater darwinulids (Fig. 2A). One of the conchostracans (Figs. 2B, C) is probably the form noted by Powers (1916) and Klein (1962), but the other (Fig. 2D) is a new estheriid-like form



Figure 1. Lower and middle Blomidon Formation locality map: 1-St. Marys Bay; 2-Central Clarence; 3-Delhaven; 4-Blomidon; 5-Lower Blomidon; 6-North Medford. C=conchostracans; f=fish; O=ostracodes; P=plants.

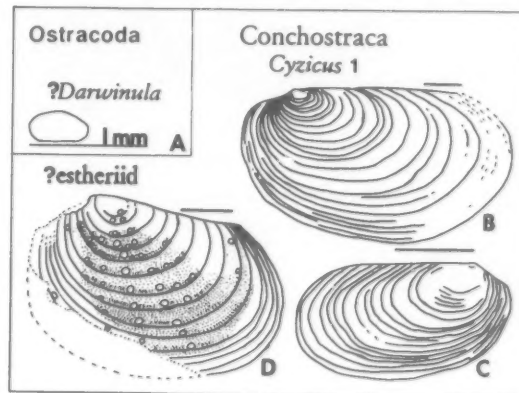


Figure 2. Line drawings from scanning electron microscope photomicrographs of freshwater crustaceans from the lower Blomidon Formation at Blomidon, Nova Scotia: A-*?Darwinula* sp.; B,C-*Cyzicus* cf. *C. ovata* (left and right valves, respectively); D-unidentified estheriid (incomplete left valve). All bar scales are 1 mm.

with (1) radiating rows of megascopic nodes, (2) granular and costate surface micro-ornamentation, and (3) small spines along the edges of growth lines. Other fossils found include semionotid(?) fish from Blomidon and invertebrate trace fossils from St. Marys Bay. A Late Triassic age for the Blomidon is still indicated by fossils.

MEANDERING STREAM DEPOSITS

Interpretations of the paleoenvironments of the Blomidon Formation have been controversial, including lacustrine and deltaic (Klein, 1962), lacustrine and fluvial (Jensen, 1975), playa and alluvial fan (Hubert and Hyde, 1982), and playa and fluvial (Cameron and Jong, 1985). All of the above authors noted the presence of channels, but there are 2 major fluvial features of the Blomidon Formation in the Digby and Delhaven areas that are also good criteria for meandering streams. These include (1) meandering river facies sequences composed of fining upwards cycles (localities 1, 3, 4, and 6 of Fig. 1) and (2) well developed lateral accretion surfaces associated with point-bar deposits (localities 1, 3, and 6 of Fig. 1).

Fining upwards cycles at St. Marys Bay (Fig. 1) were illustrated by Klein (Fig. 4, 1962) and recognized by Hubert and Hyde (Fig. 3, 1982). While Klein emphasized the lacustrine model, the latter proposed the playa

interpretation and considered the channel deposits as avulsions on an alluvial fan. Similar cyclic sequences occur at North Medford (Fig. 3 of Klein, 1962) where the Wolfville Formation/Blomidon Formation contact occurs within a cycle. Characteristically, there is a sharp, scoured base followed by coarse grained, in-channel deposits that are succeeded by vertically accreted floodplain fines. Some sand lenses near the top of the coarser lower part of the cycles probably represent chute channels, while others in the upper part are probably crevasse splays within overbank fines. The upper part also contains paleosol caliche horizons, desiccation cracks and root/burrow traces.

Remarkably well preserved lateral accretion surfaces (epsilon cross strata) with associated point-bar deposits are well exposed in a 2 m sandstone horizon along the Delhaven shore (locality 3, Fig. 1). This sand body exhibits an erosive base, basal channel lag conglomerates, cut banks,

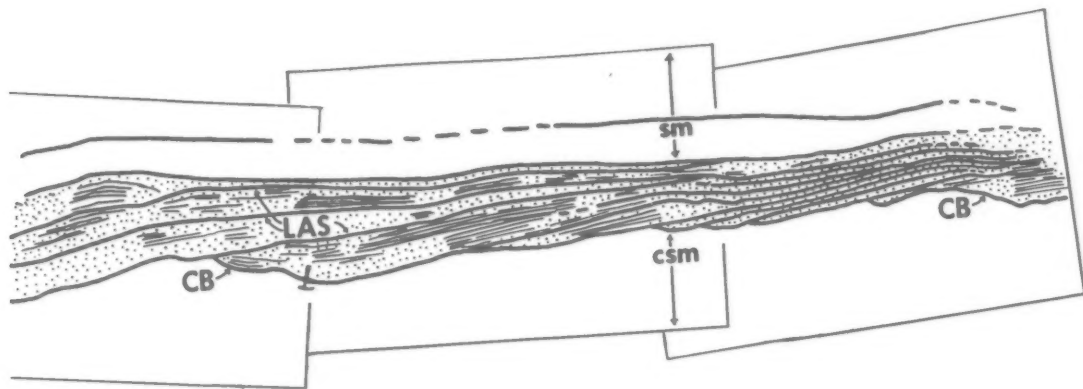


Figure 3. Line tracing from field photomosaic of a 2 m thick sand body in a fining upwards fluvial sequence at Delhaven (locality 3) illustrating a scoured base overlying floodplain convoluted (?liguified) sandy mudstones (csm), cut banks (CB), lateral accretion surfaces (LAS), cross-bedded point-bar sandstones grading laterally into thinner and finer grained sandstones and sandy mudstones, and overlying finer grained overbank sandy mudstones (sm). Geology hammer (33 cm high) for vertical scale; horizontal distance is about 33 m.

inclined lateral accretion surfaces, and cross-laminated point-bar sands that thin eastward and grade into fluviially reworked aeolian sands and overbank mudstones (Fig. 3). Other examples of lateral accretion bedding occur at North Medford, Blomidon and St. Marys Bay.

REVISED DEPOSITIONAL MODEL

This part of the Late Triassic graben valley-fill contains a fluvial "couplet" composed of a coarse braided river unit, the Wolfville Formation, succeeded by an overlying finer grained meandering river unit, the Blomidon Formation. Such couplets have been recognized only recently elsewhere in similar fluvial sequences (Jackson, 1978). The fossil ostracodes and conchostracans, trace fossils and fish remains occur in the upper parts of a few of the fluvial fining upwards cycles. It appears that some of these organisms may have lived and(or) were fossilized in either meandering river point-bar swales or temporary playa lakes on floodplains.

ACKNOWLEDGMENT

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THE GEOLOGY, MINERALOGY AND GEOCHEMISTRY OF THE KEMPT SNARE LAKE GREISEN CUPOLA, YARMOUTH COUNTY, NOVA SCOTIA¹

T. P. Soehl², G. A. O'Reilly and D. B. Clarke²

INTRODUCTION

Kempt Snare Lake is located just south of the community of Kemptville, approximately 40 km northeast of Yarmouth. This area of southwest Nova Scotia hosts a number of Sn-W and base metal mineral deposits, many of which have characteristics suggestive of a granite-related origin (Fig. 1). The quartz veins bearing scheelite, galena, sphalerite and arsenopyrite at Kempt Snare Lake occur within a small cupola of greisenized leucogranite which has intruded Lower Paleozoic Goldenville Formation metasedimentary rocks.

In the late 1920s galena and sphalerite-bearing float was discovered in this area, resulting in the sinking of a 23 m shaft on a series of quartz veins in what was believed to be quartz diorite (Taylor, 1969). Significant assays of Au (2 oz/ton) and Ag (5 oz/ton) were also reported but the host minerals of these elements have not been determined.

The prospect remained abandoned from the mid 1930s until 1985 when Kidd Creek Mines Limited, followed by Falconbridge Limited, undertook

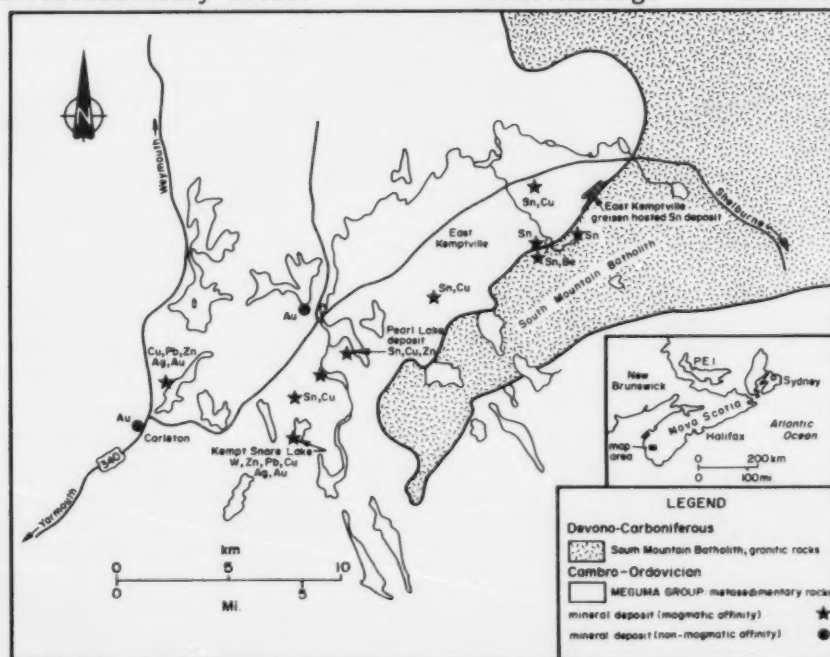


Figure 1. Generalized geology map of the East Kemptville area, southwest Nova Scotia, showing the location of the Kempt Snare Lake gneisen cupola. Locations of other mineral deposits of magmatic and non-magmatic affinity are given.

¹Funded by NSERC and by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement

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geochemical and geophysical surveys (Duncan, 1986). It was recognized at that time that the quartz diorite is actually a very highly evolved, greisenized porphyritic granite and that the dump contained a significant amount of scheelite. These conclusions led to a three hole diamond-drill program (summer 1986) totalling 202 m. The drilling intersected W, Pb, Zn and Ag mineralization but failed to confirm the presence of Au.

At present, Falconbridge retains the mineral rights and has provided the drill core for detailed geological, mineralogical and geochemical studies to be undertaken by the first author as a thesis topic. The project is jointly supervised and funded by Dalhousie University under an NSERC Undergraduate Student Research Award and the Nova Scotia Department of Mines and Energy under the current Canada-Nova Scotia Mineral Development Agreement.

SUMMARY

Lack of outcrop limited field investigations to plane table mapping of the prospect site and sampling of the large waste rock dump. Drill core logging allowed for the recognition of several textural and compositional, but mutually gradational, facies of greisen. The greisens vary in colour from black to dark grey and in texture from coarse grained porphyritic to fine grained equigranular. Observed

relations suggest that the greisens developed by hydrothermal alteration of a light grey, medium grained leucogranite.

Samples of the various greisen facies and the leucogranite have been submitted for whole-rock major and trace element geochemistry. Electron microprobe analyses of major and trace minerals are also in progress. A sample of the least altered version of the leucogranite has been submitted for $^{40}\text{Ar}/^{39}\text{Ar}$ age determination of potassium feldspar and muscovite mineral separates.

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THE FOURCHU GROUP AND ASSOCIATED GRANITOID ROCKS OF SOUTHEASTERN CAPE BRETON ISLAND, NOVA SCOTIA¹

S. M. Barr², A. S. MacDonald² and C. E. White²

INTRODUCTION

The Fourchu Group (Weeks, 1954) of southeastern Cape Breton Island consists of metavolcanic and less abundant metasedimentary rocks of probable late Precambrian age. It is intruded by large granitoid plutons of late Precambrian to Cambrian age. These rocks occur in five belts (Fig. 1), herein referred to as Coastal, Stirling, East Bay Hills, Sporting Mountain and Coxheath Hills, which are separated by younger, mainly sedimentary units. The Fourchu Group and associated granitoid plutons have been a focus for mineral exploration, and significant deposits are known to be present (e.g. Cu-Mo-Au in the Coxheath Hills belt and Zn-Pb-Cu-Ag-Au in the Stirling belt). Although various studies have been done in the region (Helmstaedt and Tella, 1973; Smith, 1978; Keppie et al., 1979; Mosher, 1979; Macdonald, 1983; McMullin, 1984; Rowan, 1985; Sexton, 1987; Thicke, 1987), the Fourchu Group has not been systematically remapped since Weeks regional mapped the area in 1954.

PURPOSE OF THE PROJECT

This project will produce geological maps of the Fourchu Group and associated granitoid rocks at a scale of 1:25 000, based on mapping by the authors but also incorporating data from other, more localized studies (cited previously). Major goals are to

compare stratigraphy and tectonic environment among the five belts, and to describe and interpret metallogenic environments within each belt. In addition to regional mapping, the project includes petrochemical studies of igneous units, interpretation of the structural history of the area, studies of the physical volcanology of representative areas and radiometric dating of appropriate units.

PROGRESS REPORT

During the summer of 1987, geological mapping of the East Bay Hills was completed, tying into earlier work in the Sporting Mountain area (Sexton, 1987), the East Bay Hills (McMullin, 1984; Thicke, 1987), and the Coxheath Hills (Barr and Setter, 1986; Thicke, 1987). Mapping was also done in the southwestern parts of the Stirling and Coastal belts (Fig. 1).

In the East Bay Hills the rocks are dominantly crystal and crystallitic tuffs and rare flows, ranging in composition from basaltic to rhyolitic. The more mafic tuffs are commonly interlayered with basaltic flow(?) breccias. Fine grained clastic metasedimentary rocks occur rarely, interlayered with the metavolcanic rocks. In the southwest, along Bras D'Or Lake, the rocks are dominantly porphyritic rhyolites, with minor rhyolitic lithic tuffs. These units are intruded by Late Hadrynian-Cambrian plutons, including MacEachern

¹ Funded by Geological Survey of Canada under the Canada - Nova Scotia Mineral Development Agreement

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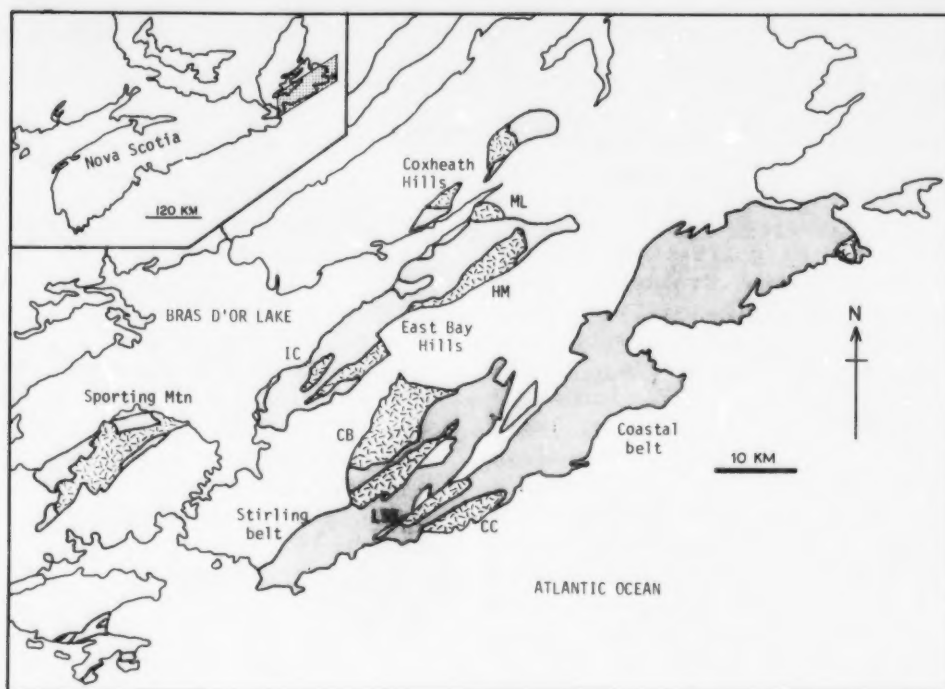


Figure 1. Distribution of the Fourchu Group (grey) and associated Late Hadrynian-Early Cambrian granitoid rocks (dash pattern) in southeastern Cape Breton Island. ML=MacEachern Lake pluton, HM=Huntington Mountain pluton; IC=Irish Cove pluton; CB=Chisholm Brook plutonic suite; LSE=Lower St. Esprit pluton; CC=Capelin Cove pluton.

Lake (monzogranite, granodiorite, and quartz diorite; Thicke, 1987) and Huntington Mountain (ranging from diorite to leucogranite; Barr et al., 1982) in the northeast, and the Irish Cove monzogranite suite (McMullin, 1984) in the southwest.

The southwestern portion of the Stirling belt is dominated by intermediate to mafic lithic tuff and turbiditic greywacke-siltstone sequences. Subordinate units include basaltic flows, abundant porphyritic basaltic and gabbroic sheets, felsic lithic-crystal tuffs, and subvolcanic(?) porphyritic quartz-feldspar rhyodacite. Granitoid rocks intruding the belt include leucocratic biotite granite of unknown age and dioritic to granitic plutons of the Chisholm Brook suite (Late Hadrynian-Early Cambrian). Intraformational conglomerate, locally associated with the

greywacke-siltstone sequences, contains granitoid clasts, suggesting that there was contemporaneous unroofing of granitoid plutons either in the Stirling belt or in the adjacent Coastal belt. Rocks of the Stirling belt are separated from those of the Coastal belt by Lower Cambrian(?) clastic rocks and(or) major faulting.

The Coastal belt in the southwestern part of the map area consists dominantly of crystal tuff of intermediate (dacitic) composition, with subordinate crystal-lithic tuff, porphyritic dacite and subaerial basalt flows. These are intruded by granitoid rocks, previously referred to as the Capelin Cove pluton (O'Reilly, 1977) from which a Rb-Sr whole rock isochron yielded a late Precambrian-Early Cambrian age (Cormier, 1972). However, the mapping of the authors indicates that this pluton consists of two

distinct and physically separate units, the strongly deformed Capelin Cove granite in the southeast and the undeformed Lower St. Esprit hornblende-biotite granodiorite to the northwest. It is probable that these two units are of different ages.

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GEOLOGICAL MAP OF THE IGNEOUS AND METAMORPHIC ROCKS OF NORTHERN CAPE BRETON ISLAND, NOVA SCOTIA¹

S. M. Barr², R. P. Raeside² and R. A. Jamieson³

INTRODUCTION

Results of recent geological mapping of the igneous and metamorphic rocks of the Cape Breton Highlands, Kellys Mountain, Gillanders Mountain and the Mabou Highlands were compiled

at the 1:50 000 scale (Barr *et al.*, 1987a). This compilation includes data from publications and theses in those areas identified and referenced on Figure 1. Most of the mapping was conducted at the 1:10 000 scale, and first compiled at the 1:25 000 scale.

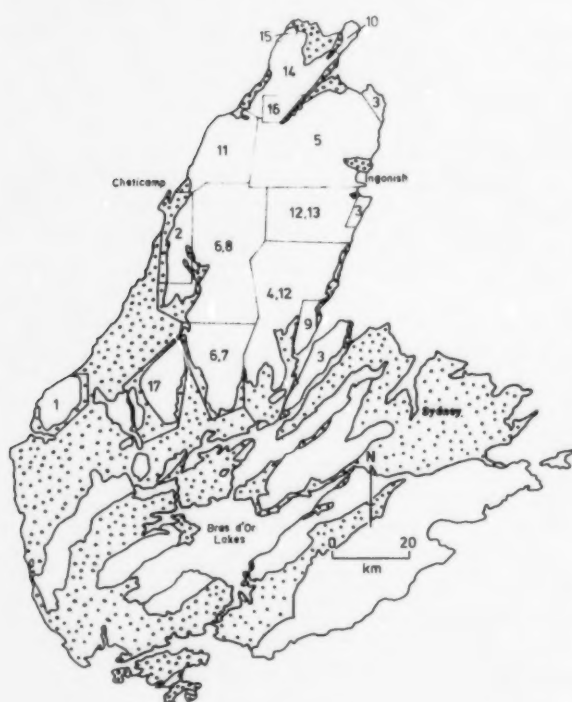


Figure 1. Simplified map of Cape Breton Island, showing the distribution of igneous and metamorphic rocks (unshaded) and unmetamorphosed sedimentary rocks (shaded). Numbers refer to sources for the compilation of the geology of northern Cape Breton Island. 1 - Barr and Macdonald, in press; 2 - Barr *et al.*, 1986; 3 - Barr *et al.*, 1982; 4 - Barr *et al.*, 1985; 5 - Barr *et al.*, 1987; 6 - Jamieson and Craw, 1983; 7 - Jamieson and Doucet, 1983; 8 - Jamieson *et al.*, in press; 9 - Macdonald and Barr, 1985; 10 - Macdonald and Smith, 1980; 11 - Pint *et al.*, 1986; 12 - Raeside and Barr, 1986; 13 - Raeside *et al.*, 1984; 14 - Raeside *et al.*, 1986; 15 - Smith and Macdonald, 1981; 16 - Smith and Macdonald, 1983; 17 - French 1985.

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GEOLOGY AND METAMORPHISM OF THE LIME HILL GNEISSIC COMPLEX, INVERNESS COUNTY, CAPE BRETON ISLAND¹

R. P. Raeside²

INTRODUCTION

The pre-Carboniferous rocks of central Cape Breton Island constitute part of the Bras d'Or Zone (Barr and Raeside, 1986). This zone (Fig. 1) is characterized by several basement blocks in which occur Precambrian rocks of the George River Group including quartzite, greywacke, slate, marble and minor mafic volcanic rocks. The Bras d'Or Zone is intruded by large plutons of apparent Ordovician age (Barr and Setter, 1984; Barr et al. 1982, 1985), which bear similarities to plutons ascribed to the Aspy and Ingonish Zones. The lower Paleozoic and Precambrian rocks of the western Bras d'Or Zone are overlain by Devonian volcanic rocks of the Fisset Brook Formation. The Bras d'Or Zone appears transitional between the recognized Avalonian rocks of southeastern Cape Breton Island, and the higher grade and more severely deformed rocks with possible Grenvillian affinities in northern Cape Breton Island.

The diagnostic unit of the Bras d'Or Zone is the George River Group, which is typically low metamorphic grade, except where it has been intruded by post-metamorphic plutons. Areas where higher metamorphic grade gneiss and schist also occur in the Bras d'Or Zone include the Kellys Mountain Gneiss (Barr et al., 1982; Jamieson, 1984), and smaller blocks in the Boisdale Hills, Creignish Hills and the North Mountain. A detailed

petrological study of the Kellys Mountain Gneiss (Jamieson, 1984) indicates low pressure metamorphism related to the intrusion of diorite which resulted in the development of cordierite migmatites.

THE LIME HILL GNEISSIC COMPLEX

The Lime Hill gneissic complex occurs in the North Mountain, southern Inverness County. Previous mapping designated the complex as either part of the George River Group (Kelley, 1967) or as inclusions in Paleozoic granite (Milligan, 1970). Recent mapping of the North Mountain (Justino, 1985) and the Lime Hill zinc showing (Justino and Sangster, 1987) has shown that (1) low grade rocks of the George River Group are in fault contact with the Lime Hill gneissic complex, and (2) the gneissic lithologies are more extensive than previously recognized, occurring in two blocks on either side of the North Mountain. Both blocks were intruded by tonalitic to granodioritic and granitic plutons, and by numerous granitoid and mafic dykes which preserved metasomatic aureoles where they intruded carbonate-bearing rocks (Justino and Sangster, 1987).

The gneissic complex exhibits a uniform high metamorphic grade and includes biotite gneiss, cordierite-biotite gneiss, amphibolite and a variety of carbonate-bearing lithologies. Biotite gneiss is the most abundant phase and is composed of

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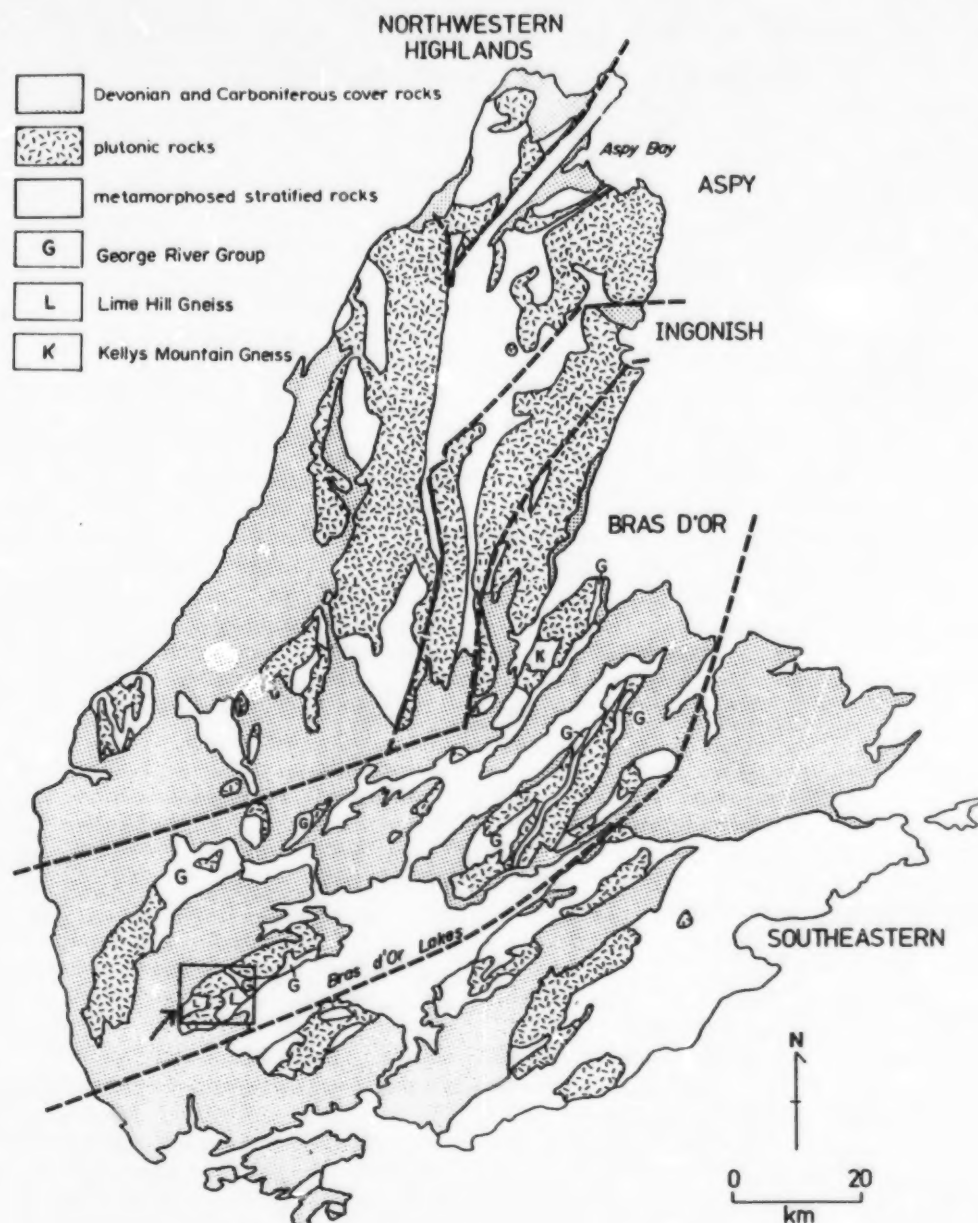


Figure 1. Location of the Lime Hill Gneiss and tectonostratigraphic subdivisions of Cape Breton Island (after Barr and Raeside, 1986).

quartz, orthoclase, biotite and plagioclase. Prograde muscovite is absent. Hypersthene, augite or garnet may be present and Fe-Ti oxides are ubiquitous. Cordierite-biotite gneiss occurs as a well layered migmatitic rock, and the cordierite is restricted to the quartzofeldspathic (leucosome)

layers. Sillimanite is commonly associated with the cordierite, and andalusite, spinel and corundum are also present.

Amphibolite (including hornblende-biotite gneiss) which may contain clinopyroxene, is a subordinate

lithology. Carbonate-bearing and calc-silicate lithologies are minor but exhibit a wide range of mineral assemblages.

METAMORPHIC CONDITIONS INFERRED FROM ASSEMBLAGES

The maximum prograde metamorphic assemblage is biotite, cordierite, sillimanite, plagioclase, orthoclase, quartz, garnet, ilmenite, magnetite and melt. This assemblage limits the peak metamorphism, on the basis of the aluminosilicate stability and on various melt-producing reactions, to the 300-450 MPa range and over 700°C. Hercynite spinel and corundum in sillimanite-garnet-cordierite assemblages are probably the result of desilication during anatexis at temperatures below 720°C (Harris, 1981).

Garnet-biotite geothermometry and garnet-plagioclase-sillimanite-quartz geobarometry yielded equilibration temperatures and pressures of 740-780°C and 300-400 MPa, respectively. These values are in close agreement with conditions predicted by analysis of the phases present.

Retrograde metamorphism, which is prevalent in much of the gneiss, is indicated by the development of andalusite, muscovite, sericite, pinite and chlorite.

REGIONAL CORRELATION OF THE LIME HILL GNEISSIC COMPLEX

The quartzofeldspathic and amphibolitic gneisses bear many similarities to the Kellys Mountain Gneiss. The absence of prograde muscovite and the presence of the cordierite-andalusite/sillimanite-melt assemblage, are particularly characteristic of low pressure, upper amphibolite facies metamorphism. The agent of this metamorphism may have been heat evolved from the intrusion of plutons as suggested for diorite at Kellys Mountain (Jamieson, 1984).

However, the recognition of a number of high grade-low pressure gneisses in the Bras d'Or Zone indicates that a more regional high heat flow event was responsible for the metamorphism, and the association with plutons may be secondary to the original source of the heat, serving mainly to develop "hot spots" within the zone. This extensive development of low pressure amphibolite facies metamorphism is not typical of the Grenvillian rocks exposed in northwestern Cape Breton Island (Barr et al., 1987), implying that the Bras d'Or Zone is not underlain by Grenvillian basement.

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SUMMARY OF THE GEOLOGY OF THE EASTERN COBEQUID HIGHLANDS¹J. B. Murphy², G. Pe-Piper³, R. D. Nance⁴ and D. S. Turner³

SUMMARY

Pre-Pennsylvanian rocks of the eastern Cobequid Highlands were mapped at a scale of 1:10 000 during the summer of 1987. The area was previously mapped by Donohoe and Wallace (1982). The area is bounded to the south by the Cobequid Fault and to the north and east by Devonian-Carboniferous rocks which unconformably overlie the basement rocks of the Cobequid Highlands. The mapping has resulted in a re-evaluation of the distribution of these rocks and the interpretation of their geological histories.

The oldest rocks belong to the Bass River and Mount Thom Complexes, which consist of ortho- and paragneisses (i.e. Great Village River Gneisses, Mount Thom Complex). These rocks are overlain by quartzites, minor marble, muscovite-biotite schists and phyllites (Gamble Brook Formation), which occur only to the south of the Rockland Brook Fault. The present contact between the Great Village River Gneiss and the Gamble Brook Formation is a ductile shear zone. This shear zone obscures the original relationships, but the contact may have been an unconformity. If correlation with similar lithologies in New Brunswick is accepted as suggested by Donohoe (1983), then the deposition of the Gamble Brook Formation may be mid-

Riphean in age. The Gamble Brook Formation has been metamorphosed from mid-greenschist to lower amphibolite facies. The Gamble Brook Formation is unconformably overlain by Folly River Formation, which consists of a complex of mafic dykes and submarine flows with interlayered turbidites and pelagic sediments. Therefore, the Folly River Formation may document a younger tectonic environment than the Gamble Brook Formation.

Preliminary geochemical data suggest that the volcanic rocks are within-plate tholeiites with alkalic affinities. These features and the association of abundant dykes suggest the rocks were emplaced in an extensional environment. The age of the Folly Lake Formation is uncertain, but it may be as young as Late Precambrian and a correlative of the Jeffers Group. The sequence has been metamorphosed to the greenschist facies. Intrusion of granite (now granite gneiss) appears to be synchronous with the deformation of the Gamble Brook Formation. Late Precambrian intrusions of granite (e.g. Donohoe *et al.*, 1986) are dated as post-tectonic with respect to deformation of the Gamble Brook and Folly River Formations.

The style of deformation in the Gamble Brook Formation is different from that of the Folly River Formation,

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as the former probably represents sinistral transtension. This deformation produced a mylonitic fabric adjacent to the contact with the Great Village River Gneiss, local CS fabrics and isoclinal folds. Bedding is strongly transposed adjacent to the contacts with the gneisses, but may be readily distinguished in many areas. The deformation of the Folly River Formation may have involved dextral transpression. It is similar to that observed in the Jeffers Group and Warwick Mountain Formation and probably involved thrusting, isoclinal folding and the local development of a penetrative flat-lying cleavage. It is tentatively suggested that the deformation in the Gamble Brook and Folly River Formations may represent the opening and closing, respectively, of an inter- or back-arc basin, possibly contemporaneous with those of the Antigonish Highlands and western Cobequid Highlands. Thus much of the deformation in the Bass River Complex may be genetically associated with Late Precambrian subduction in Nova Scotia.

To the north of the Rockland Brook Fault, Late Precambrian rocks are represented by the Jeffers Group in the extreme west and the Warwick Mountain Formation in the north. These units consist of mafic to felsic volcanic flows, tuffs and interlayered turbidites. The rocks are characterized by a flat-lying cleavage associated with isoclinal subrecumbent folds and thrusts. There is no independent evidence within the map area for the age of this deformation, but in the western Cobequid Highlands the flat-lying cleavage in the Jeffers Group is cut by Late Precambrian appinitic gabbro.

Late Precambrian diorite and granite plutons between the Debert and North Rivers have been mapped in detail. Mineralogical and geochemical studies of the Frog Lake diorite show that it is an appinite developed from a volatile-rich alkaline magma enriched

in sulphides. This diorite occurs in small stocks and sills, and is cut by later high level Late Precambrian granites, which are in turn intruded by Carboniferous granites.

Cambrian to Lower Ordovician strata are not represented in the area. Upper Ordovician - Lower Devonian rocks comprise the Wilson Brook Formation, which is lithologically similar to the Arisaig Group of the Antigonish Highlands. Silurian volcanism (Earlton volcanics) in the eastern Cobequids is not as extensive as previously considered (Donohoe and Wallace, 1982); most of these sequences have been reassigned to the Late Precambrian Warwick Formation. It is tentatively suggested that the Earlton Formation be abandoned and the Silurian sediments in this area be assigned to the Wilson Brook Formation. Silurian volcanics may occur in the west of the area and the western Cobequids, and with further work a new Silurian volcanic sequence may be defined.

The Late Devonian - Carboniferous rocks are dominated by bimodal volcanics (Fountain Lake Group, Byers Brook and Diamond Brook Formations); the detailed field relationships between the volcanic sequences are unclear. The sequences are intruded by granite, diorite and gabbro plutons of Devonian and Carboniferous age.

Remapping of the area between West Brook and Wyvern, previously mapped as the Wyvern and Gilbert Plutons, has shown that this poorly exposed area in the northern Cobequid Hills includes major gabbro-diorite plutons, a distinctive white granite (with collisional granite geochemical signature), and a series of steeply dipping pyroclastic rocks and basalts of unknown age. There is also an apparent continuation of the Byers Lake - Hart Lake Pluton in this area.

The Folly Lake and Economy River Plutons of Devonian-Carboniferous age are

complexes of early fine- to coarse-grained gabbro intruded first by porphyritic and later by fine grained equigranular diorite. The Folly Lake Pluton was intruded by pervasive pink fine grained granitic dykes and sills, which are locally pegmatitic. This pluton intrudes Devonian-Carboniferous Fountain Lake rhyolite and is intruded by Hart Lake - Byers Lake Pluton dated as Carboniferous (Donohoe *et al.*, 1986).

Carboniferous plutons, comprising the Hart Lake - Byers Lake Pluton and the Pleasant Hills Pluton, are distinctive pink coarse grained granites. Some pegmatite veins cutting the granite contain magnetite and chalcopyrite mineralization.

The entire area was deformed locally by thrusts and high angle reverse faults folds subsequent to intrusion of the Carboniferous plutons and the deposition of the Tournaisian Nuttby Formation, but synchronous with, or prior to, the Namurian. This deformation is probably associated with dextral motion on major east-west trending faults which locally impart a mylonitic fabric.

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SEQUENCE OF STRUCTURAL, METAMORPHIC AND INTRUSIVE EVENTS IN THE CANSO AND FOREST HILL MAP AREAS, EASTERN MEGUMA TERRANE, NOVA SCOTIA¹

J. D. Hill²

Mapping of the Canso (210 km² at 1:25 000 scale) and Forest Hill (300 km² at 1:50 000) areas was completed in 1985 and 1986 to evaluate the tectonic evolution, petrogenesis and economic potential of the granitoid plutons. The final report, a Geological Survey of Canada Bulletin, and colored maps are expected to be in press by late 1987. The locations of the 2 map areas and general geology of mainland Nova Scotia are shown in Figure 1. This current contribution is aimed at elucidating the sequence of structural, metamorphic and intrusive events that affected the eastern Meguma terrane, as revealed in the Canso and Forest Hill areas.

Deformation and metamorphism are assigned to 3 events, namely D₁ to D₃, which together represent continuous or almost continuous tectonism from early Devonian to early Carboniferous or later (Table 1). Event D₁ is correlated with the Acadian Orogeny which developed in response to continental collision between the Meguma and Avalon terranes (Keppie, 1977; Schenk, 1978). The suture between the two terranes is defined by the Cobequid-Chedabucto fault system. The Acadian Orogeny was followed by a complex polyphase event (D₂) of ductile shearing and subsequent brittle deformation which was associated with dextral transcurrent movements along the Cobequid-Chedabucto fault system

(e.g. Mawer and White, 1987). These movements appear to have been the result of post-accretionary adjustments and possibly additional oblique collisions among the outboard blocks of that part of the Appalachian orogen (Williams and Hatcher, 1982; Keppie, 1985). The final event (D₃) is defined by faulting which occurred during or after the early Carboniferous. Emplacement of several small tonalite plutons occurred after D₁ and before D₂. Uranium-lead zircon dates of ca. 378 Ma, determined by T. Krogh of the Royal Ontario Museum, have been obtained for two of the plutons. Numerous granitic peraluminous plutons were emplaced during D₂. Three U-Pb monazite dates indicate most (and perhaps all) plutons crystallized between 371 and 373 Ma. Only tenuous evidence for D₁ exists in the Canso and Forest Hill map areas because of overprinting effects of D₂.

Stratigraphic repetition in the Meguma Group implies the presence of km-scale east trending synclines and anticlines. Absence of closures suggests that they are subhorizontal. They are correlated with D₁ because they lack obvious asymmetry (like D₂ folds) and because they are identical to Acadian structures recognized farther southwest in less deformed parts of the Meguma terrane. Minor folds with similar style and locally preserved schistosity are also assigned

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to D_1 because they are deformed by earliest D_2 structures or because they occur in areas where D_2 is weak or absent. Limited evidence suggests that upper greenschist conditions prevailed. Mica, defining S_1 slaty cleavage farther to the southwest in the Meguma terrane, has been dated at 384-415 Ma (Reynolds and Muecke, 1978; Dallmeyer and Keppie, 1987).

The D_2 event is comprised of a series of overlapping phases of deformation, metamorphism and granitic intrusion. The first 3 phases of deformation (D_{2a} to D_{2c}) produced a 10-15 km wide ductile shear zone along the south side of the Cobequid-Chedabucto fault system. Structures within the shear zone are remarkably similar to those developed in the South American shear zone in France (Berthé et al., 1979). The D_2 strain was heterogeneous, resulting in a high proportion of mylonitic rocks concentrated in narrow east trending shear zones which are bound to the north and south by less deformed rocks. Tight to isoclinal

folds (mm to 100 m scale) with dextral vergence are intrafolial to layer-parallel transposition foliation in metasedimentary rocks. Spaced shear planes (C-planes) dextrally deform a penetrative grain flattening foliation (S-fabric) in granitoid rocks. As shear zone centres are approached, the proportion of C-planes increases to 5-10 per cm and the angle between S and C-planes decreases to $10-20^\circ$. East trending mineral extension lineation and striations suggest that movement was subhorizontal. Kinematic indicators (e.g. asymmetric folds, winged porphyroblasts and S-C fabric) point to dextral rotation. Mineral assemblages related to D_{2a} , D_{2c} and D_{2d} ductile deformation indicate upper greenschist facies conditions existed except where higher temperatures were caused by intrusion of granitic plutons between D_{2a} and D_{2b} .

The last 2 phases of D_2 point to increasingly brittle deformation as temperature decreased. The D_{2d} event includes a variety of small open folds

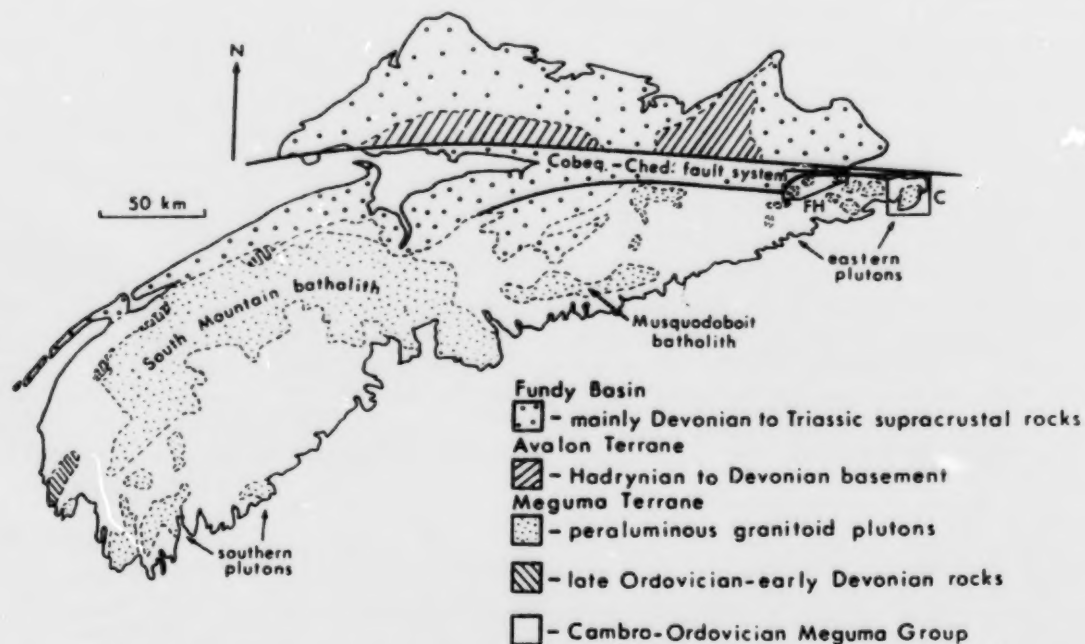


Figure 1. General geology of mainland Nova Scotia; the locations of the Canso (C) and Forest Hill (FH) map areas in the eastern Meguma terrane are outlined.

Table 1. Summary of the structural, metamorphic and intrusive history of the Canso and Forest Hill map areas. D₁ is correlated with the Acadian Orogeny. D₂ is attributed to dextral transcurrent shearing within 10-15 km of the Cobequid-Chedabucto fault system. D₃ includes all Carboniferous and younger fault movements.

Event Age(Ma)	Description
D ₃ -	Vertical movement on Guysborough County fault; sinistral transcurrent movement on northwest trending Country Harbour and Kyak Brook faults; near-surface P-T conditions
360 -	D _{2e} : Riedel shear package of transcurrent faults and brittle-ductile shear zones; rare kink folds and kink bands; lower greenschist facies (and lower?)
	D _{2d} : regionally non-penetrative crenulation cleavages and small open folds; partly overlapped D _{2c} and possibly D _{2b} ; lower greenschist facies
	D _{2c} : isoclinal asymmetric folds; east trending crenulation cleavage and S-C fabric; upper greenschist facies
D ₂ -	D _{2b} : isoclinal asymmetric folds; east to northeast trending transposition foliation in metasedimentary rocks and mylonitic S-C fabric in granitic rocks; subhorizontal mineral lineation and striations; overlapped granitic plutonism and static metamorphism; upper greenschist facies
372±1 -	Granitic plutonism: numerous biotite-muscovite granite and minor granodiorite plutons; overlapped D _{2b} ; amphibolite facies hornfels developed locally by contact metamorphism
	Static metamorphism: widespread growth of fibrolite knots and porphyroblasts of biotite, andalusite, cordierite and staurolite in schistose metapelites; overlapped D _{2a} and D _{2b} ; upper greenschist to middle amphibolite facies
	D _{2a} : isoclinal asymmetric folds; east trending transposition foliation; overlapped static metamorphism; upper greenschist facies
378±2 -	Tonalite plutonism: intrusion of several small bodies of tonalite; contact metamorphic effects unknown
D ₁ -	~400 - structures largely obliterated by D ₂ ; km-scale synclines and anticlines inferred from stratigraphic repetition; small folds and schistosity locally preserved where D ₂ weak or absent; upper greenschist facies

and crenulation cleavages which are regionally non-penetrative. They formed during lower greenschist facies metamorphism. The culmination of D₂ is marked with a Riedel shear package of transcurrent faults and brittle-ductile shear zones which developed during D_{2a} under near-surface P-T conditions. The change in P-T conditions during the latter part of D₂ corresponds to 11-16 km of uplift over a 10-20 Ma period. This gives an average uplift rate of 0.05-0.1 cm/year.

A period of 'static' metamorphic and granitic intrusion occurred between and overlapped D_{2a} and D_{2b}. 'Static' metamorphic assemblages are marked by the widespread growth of sillimanite knots and porphyroblasts of biotite, andalusite, cordierite and staurolite in schistose pelitic rocks. The same minerals are present in relatively rare hornfels which obviously formed by local contact metamorphism related to intrusion of granitic plutons. It is inferred that uprise of granitic magmas, generated in the lower crust, accounted for the elevated temperatures at ca. 372 Ma. Therefore, both contact and 'static' metamorphism were caused by plutonism. Mineral assemblages indicate that the current level of exposure corresponds to depths of 11-16 km. The heat source for regional metamorphism and partial melting appears to have been crustal thickening during D₁ and early D₂, possibly augmented by uprise of hotter magmas from below (e.g. tonalite). The D₂ deformational event is tightly constrained in time; it began after tonalite intrusion at ca. 378 Ma and ended by the early Carboniferous (350-360 Ma) when the Horton Group was deposited.

The brittle end stages of D₂ were closely followed by additional near surface cataclastic deformation (D₃) related to local faulting. Examples include vertical movements on the Guysborough County fault and sinistral transcurrent displacement on the

Country Harbour fault, both of which affected the early Carboniferous Gunns Brook formation (correlated with the Horton Group) in the Forest Hill area.

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SULPHUR ISOTOPE STUDIES, MEGUMA TERRANE, NOVA SCOTIA: A PRELIMINARY REPORT¹

A. L. Sangster²

A preliminary study of sulphur isotope compositions of regionally distributed pyrite and pyrrhotite and of arsenopyrite and pyrrhotite from gold occurrences in the Meguma Terrane suggests that such studies may significantly advance the understanding of genetic controls on base metal and gold mineralization. This brief report presents the results of analyses as follows:

1. 10 analyses on pyrrhotite from DDH 1224-27, Eastville (St. Joseph Explorations),
2. 12 analyses on pyrrhotite and 2 analyses on pyrite from DDH LC-1, Lake Charlotte (drilled by the Nova Scotia Department of Mines and Energy in support of Cuesta Research Limited contract with the Geological Survey of Canada),
3. 17 analyses on arsenopyrite and 3 analyses on pyrrhotite from the Lawrencetown gold occurrence, and
4. 16 analyses on arsenopyrite and 1 analysis on pyrrhotite from the Caribou gold occurrence.

EASTVILLE AND LAKE CHARLOTTE ANALYSES

Holes 1224-27 and LC-1 cored sections of the basal pyrrhotitic black slate of the Halifax Formation and the underlying Mn-rich cotecule of the Goldenville-Halifax Formation transition zone. The $\delta^{34}\text{S}$ values for samples from the two holes indicate a systematic, stratigraphically

controlled variation with values of -5‰ to $+22\text{‰}$ at Eastville and -8‰ to $+18\text{‰}$ at Lake Charlotte.

The Eastville values are relatively constant 100 - 200 m above the base of the Halifax Formation, commonly in the range of -5‰ to 0‰ , whereas in the 30 m above the base of the Halifax Formation (i.e. 30 m above the cotecule-bearing unit) values are as great as $+21\text{‰}$. The isotopic values are interpreted to indicate that the sulphide sulphur higher in the section was biogenically reduced under relatively open marine conditions. On the other hand, the sulphide sulphur at the base of the Halifax Formation may have been biogenically fractionated in a highly anoxic marine environment resulting in the larger isotopic ratio. These data support the conclusions of Waldron (1987), based on other evidence, that sedimentation in the basal part of the Halifax Formation occurred under highly anoxic conditions.

It is significant that the base metal geochemical anomaly in DDH 1224-27 is in rocks deposited during the period of anoxic sedimentation. This suggests the presence of a marine environmental control on base metal mineralization at Eastville similar to that documented for sediment-hosted mineralization in the Selwyn Basin, Yukon Territory (Goodfellow and Jonasson, 1984).

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GOLD OCCURRENCE ANALYSES

Sulphide samples from Lawrencetown and Caribou were selected to represent end member compositions of gold vein-bearing host rocks, typical of the Goldenville Formation. The Lawrencetown samples contain 5 - 20% arsenopyrite, with minor pyrrhotite, disseminated in black, carbonaceous argillite. The arsenopyrite commonly occurs as alternating bands of heavy and sparse disseminations parallel to lithological layering, suggesting a genetic association with sedimentary or diagenetic processes. The long axes of the sulphide grains are aligned parallel to cleavage. These features are similar to those found in regional pyrrhotite in the Halifax Formation. The Caribou samples contain 1-2 cm twinned crystals of arsenopyrite in massive, ankeritic quartzite. The arsenopyrite occurs randomly disseminated in the quartzite, showing no apparent relationship to bedding. Quartz-filled pressure shadows are common around the arsenopyrite.

Values for δS^{34} for the two suites are large and show little internal variation. The value results for the Lawrencetown arsenopyrite and pyrrhotite range from $+12^0_{00}$ to $+15^0_{00}$, and the Caribou analyses range from $+17^0_{00}$ to $+21^0_{00}$. The heavy isotopic signature precludes a direct magmatic origin for the sulphides. The similarity between these values and the maximum values reported above for sulphides from the basal part of the Halifax Formation indicates that the sulphide zones associated with these gold occurrences can be most reasonably

explained as bacterially reduced sulphide formed in an anoxic seafloor environment. This suggests that Nova Scotia gold districts are centred on anoxic, lithogeochemically anomalous (As-Fe-Au-Cu-Pb-Zn) shale basins within the Goldenville Formation and are of sedimentary or diagenetic origin. Productive gold districts have developed where subsequent tectonic stresses have led to remobilization of components from the lithogeochemically anomalous zones into the structures in which the gold mineralization is now observed.

Mineral separation and isotopic analysis of a comprehensive suite of samples, in progress, is expected to confirm the preliminary results and permit thorough evaluation of the implications of this work.

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MINERALOGY AND CHEMISTRY OF METAWACKES AND SLATES AS A GUIDE TO GOLD IN THE EASTERN MEGUMA TERRANE OF NOVA SCOTIA: A PROGRESS REPORT¹

J. A. Kerswill²

The principal goal of this investigation is to document mineralogical and chemical features of the host rocks to the gold-bearing quartz veins of the Meguma Group in an effort to establish useful indicators of gold potential. A related objective is to provide additional constraints in constructing a predictive genetic model for turbidite-hosted gold deposits. It is expected that the physical and chemical character of the host rocks to the veins played an important role in localizing gold mineralization. This work builds upon previous studies (Graves and Zentilli, 1982; Smith, 1985; Smith et al., 1985; Crockett et al., 1986; Fueten et al., 1986; Henderson and Henderson, 1986; Mawer, 1986; Haynes, 1987) and should complement other ongoing investigations (Smith and Kontak, 1986; Kontak and Smith, 1987; Hy and Williams, 1986; Graves and Zentilli, 1986; Sangster, 1987; Henderson and Henderson, 1987).

During the past two field seasons, >500 rock samples were collected from recent drill core or underground exposures in gold districts, including Lake Catcha, Tangier, Caribou, Moose River, Beaver Dam, Fifteen Mile Stream and Goldenville. In addition, >50 reference samples were collected from outcrops in areas relatively distant from known gold mineralization. In an initial attempt to determine the

mineralogical and geochemical features that can be linked to gold concentration, samples were grouped into a large number of populations according to lithology, proximity to gold-bearing veins, apparent intensity of alteration, and quantity of iron sulphides, arsenopyrite, carbonate and gold. The results based on an examination of major, minor and trace element data for a suite of 297 samples, complemented by limited petrographic information, will be presented in the poster session of the 1987 Nova Scotia Department of Mines and Energy Open House.

Field observations combined with a review of the literature provide a number of constraints when interpreting data generated during this study. The constraints are discussed as follows:

1. Gold occurs in structurally controlled quartz-rich veins hosted principally by metawackes and slates of the Goldenville Formation. A variety of quartz veins can be recognized but these fall into 4 principal types, namely, (1) bedding-parallel (BP) veins that typically display crack-seal texture, (2) en echelon veins, (3) saddle-reef veins, and (4) discordant veins, including AC and fissure veins. It is not always possible to determine with

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confidence the type of individual vein. Although all types can occur together, and there may be more than one generation of any particular type, the BP crack-seal veins are typically the earliest. The vein types adopted for this study closely follow those of Henderson and Henderson (1986).

2. Much of the mined gold was closely associated with BP crack-seal veins occurring along fold limbs of anticlinal domal structures, but commonly concentrated within ore shoots that occurred where the BP veins displayed minor folds or were intersected by discordant veins or vein systems. In some districts, as Caribou, significant gold was mined from fissure veins that apparently did not crosscut BP veins. As well, gold has been obtained from a few true saddle-reef veins (Henderson and Henderson, 1986; 1987).
3. Gold is commonly spatially associated with sulphides, including pyrrhotite, pyrite, arsenopyrite, chalcopyrite, sphalerite and galena. The sulphides occur within the veins, slates and metawackes; the relative proportion of sulphides is widely variable. However, economic concentrations of gold appear to be restricted to the veins or the vein-wallrock contact. Pyrrhotite, the generally dominant iron sulphide, is commonly more abundant than arsenopyrite, and where both are present, the arsenopyrite appears to overgrow or replace pyrrhotite. Arsenopyrite distribution may be more closely controlled by quartz veins, particularly those that are later than the crack-seal BP veins. This may help explain the lack of a consistent positive correlation between gold and arsenic (arsenopyrite), and implies that sulphur (pyrrhotite

or pyrite) may be a more reliable exploration guideline. It is not yet possible to state that there is a correlation between the amount of gold in a vein and the amount of sulphur in either the vein or the host rock, or there is a correlation between the amount of sulphur in a vein and the amount of sulphur in the host rock. The probable occurrence of several generations of sulphide minerals may make it difficult to easily evaluate interrelationships among gold and total contents of sulphur and arsenic.

4. Large-scale hydrothermal alteration zones that can be clearly linked to late gold-rich veins (Kontak and Smith, 1987) may occur in some districts. A link between such zones and gold distribution in the early BP crack-seal veins has yet to be established in this study. The lithogeochemical data from this investigation may help determine gains and(or) losses of components (SiO_2 , CO_2 , K_2O , Na_2O , S, As, Au, etc.) that accompanied gold deposition. Petrographic work should help establish whether or not particular minerals (quartz, sericite, biotite, carbonate, chlorite, arsenopyrite, pyrrhotite, pyrite, etc.) or mineral assemblages can be related to alteration associated with gold mineralization.

A predictive genetic model for Meguma Group gold deposits must not only account for the occurrence of much of the gold in early BP crack-seal veins, but also explain the apparently strong structural control on ore shoot distribution and the presence of significant gold in late fissure veins. A tentative multistage model that permits vein-controlled deposition of variable amounts of $\text{SiO}_2 \pm \text{H}_2\text{O} + \text{CO}_2 \pm \text{S} \pm \text{As} \pm \text{Au} \pm \text{Cu} \pm \text{Pb} \pm \text{Zn} \pm \text{W} \pm \text{Sb}$ from a succession of hydrothermal

fluids that were generated at various stages during the structural and metamorphic evolution of the basin seems most appropriate. The sediments were the most likely source of the vein components but transport distances from source to site of deposition may have been at the kilometre scale. Early hydrothermal fluids were generated by a combination of connate fluid release during burial, pressure solution and prograde metamorphic dehydration reactions of the greenschist facies. Fluids formed during higher grade metamorphism associated with intrusion of the Devonian granitoid rocks contributed to the later veins. Such fluids may have had a magmatic component. Remobilization of gold from early crack-seal BP veins into later veins may have occurred, but was probably not sufficient to account for the varied styles of gold distribution.

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MEGUMA GOLD DEPOSITS; NESTED SADDLE REEFS OR EARLY HYDRAULIC EXTENSION FRACTURES?¹

J. R. Henderson² and M. N. Henderson²

Faribault (1903) first drew attention to certain similarities between the Meguma Group gold fields of Nova Scotia and the Victoria gold fields of Australia by proposing that bedding-parallel auriferous quartz veins are nested on the culminations of doubly-plunging anticlines of the Goldenville Formation. Rickard (1912) observed that most of the breached Nova Scotia domes contained nested bedding-parallel veins on only one limb or one plunging nose of a doubly-plunging anticline, and questioned the assumption made by Faribault that the exposed veins were part of more extensive bodies covering the culminations of the eroded domes. However, the anticlinal saddle-reef model has an appealing simplicity and continues to receive attention as a guide to gold exploration in the Meguma Zone (Keppie, 1976; Mawer, 1986; 1987).

A geometric model of saddle-reef vein formation is discussed fully by Ramsay (1974) who shows that saddle veins can be attributed to dilation localized in hinge zones of chevron folds during late stages of fold development. Sandiford and Keays (1986) show that auriferous saddle-reefs at Ballarat and Bendigo, Victoria postdate cleavage development and folding. These authors concluded that mineralized saddle reefs and steep reverse faults formed as a result of vertical extension accompanying lateral compression after the locking-up of flexural folds in accordance with the

geometrical model of Ramsay (1974).

Graves and Zentilli (1982) approached the problem of the origin of the auriferous bedding-parallel veins from a mechanistic viewpoint. These authors showed the bedding-parallel veins could have formed as hydraulic extension fractures at the onset of horizontal compression that led to the development of folds and cleavage in the Meguma Group. Hydraulic fracturing takes place when pore fluid pressure exceeds the overburden pressure and the tensile strength of rocks. Hydraulic fractures commonly are transient phenomena and may open many times as sediments compact and lithify, and pore fluids are expelled towards the surface (Fyfe *et al.*, 1978). Ramsay (1980) illustrated vein microfabrics indicative of episodic hydraulic extension fracturing and sealing which he termed crack-seal veins. Similar crack-seal microfabrics were documented in laminated bedding-parallel veins in the Meguma Group by Henderson (1983), Henderson and Henderson (1986) and Mawer (1985), thus confirming the hydraulic fracture mechanism of vein formation postulated by Graves and Zentilli (1982). Observations made by ourselves at the Beaver Dam and Tangier mines indicate that gold at these localities occurs almost exclusively in bedding-parallel crack-seal veins.

A critical outstanding question regarding the bedding-parallel crack-seal veins is the age relative to

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cleavage formation and folding. If bedding-parallel veins pre-date the fold development they cannot be saddle-reef veins, and their association with anticlinal plunge culminations is not real as indicated by Rickard (1912).

Henderson *et al.* (1986) report some results of strain studies in the Goldenville Formation demonstrating that spaced cleavage in sandy metagreywacke beds formed before folding, and bedding-parallel veins were present *before* cleavage developed. These conclusions were drawn mainly from analysis of deformed dewatering pipes capped by sand volcanoes in metagreywacke beds. In the Halifax Formation near Blue Rocks and the Ovens, Nova Scotia the authors have studied silt-filled, paired worm tubes in slate beds. The observations of deformed worm tubes in slate fully support the conclusions drawn from observations of deformed dewatering pipe-sand volcanoes in metagreywacke. The originally vertical tubes were affected by layer-parallel shortening which produced vertical slaty cleavage oriented perpendicular to horizontal beds. Subsequently the worm tubes and slaty cleavage were sheared parallel to bedding during folding; the right angle relationship on fold limbs was destroyed, but with little distortion effecting the bedding surfaces.

Additional evidence for pre-cleavage origin of bedding-parallel crack-seal veins is provided by observations that symmetrical concentric buckle folds in mm-wide carbonate beds enclosed by slate are uncleaved and exhibit 70% buckle-shortening. Comparable shortening is shown by uncleaved and symmetrically buckled crack-seal bedding-parallel veins enclosed within slate beds. These observations confirm that buckled veins have taken up as much layer-parallel strain as carbonate beds during slaty cleavage development, and therefore must have been present at the onset of cleavage formation. This

final observation places important constraints on the timing and origin of the gold-bearing fluids. It eliminates the discordant Devonian granites as a source of heat and fluids to produce the auriferous bedding-parallel crack-seal veins, and points to pore water trapped beneath impermeable pelitic cap rocks as the mineralizing agent. The authors do not contend that true saddle reefs are absent in the Meguma Group; a saddle reef apparently was mined at Dufferin (Henderson and Henderson, 1986), and a saddle reef is exposed on the crest of the Ovens anticline at the Ovens. However they are rare, and would be poor exploration targets.

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GEOCHEMICAL CHARACTERIZATION OF THE GOLDENVILLE-HALIFAX TRANSITION OF THE MEGUMA GROUP OF NOVA SCOTIA: PROGRESS REPORT III¹

M. C. Graves² and M. Zentilli³

Work continued throughout 1986-87 on the lithogeochemical characterization of the transition between the sandy Goldenville and overlying shaly Halifax Formations (Goldenville-Halifax Transition-GHT) of the Cambro-Ordovician Meguma Group of southern Nova Scotia. The units are lithogeochemically distinct at the boundary but the geochemical signature of the transition extends at least 100 m (stratigraphically) beyond the GHT.

The authors present results from well described sections of low metamorphic grade from the Dublin Shore at the mouth of the LaHave River and drillcore from the Caribou gold district at the central part of the outcrop area (Table 1).

The variation of major and trace elements is dominated by the continuous mineralogical variation from beds rich in sand-sized quartz grains with minor feldspar and a minor clay matrix (now chlorite and muscovite) to rocks of primarily matrix (now slates). Sedimentological fractionation may account for this trend. The turbidites of the

Goldenville Formation become more thinly bedded and more sedimentologically fractionated upward to a thin gradational contact with calcareous and manganiferous argillites of the Moshers Island member of the Halifax Formation (O'Brien, 1985; Zentilli *et al.*, 1986; Waldron and Graves, 1987). The argillites are overlain sharply by a carbonaceous black shale with pyritiferous siltstones that increase in relative volume upward from the contact.

The Moshers Island argillites are the most lithogeochemically distinct with high concentrations of MnO, CO₂, As, Ba, Pb and Au. The high values are not restricted to this unit, however, as anomalous background values extend for at least tens of metres into black slates above and the calcareous slate interbeds beneath the argillites.

The results of the work continues to support the regional character of the GHT as a metallotect, and its potential usefulness as a lithogeochemical marker at the scale of the mine or prospect, during drilling or boulder tracing.

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Table 1. Lithogeochemical summary data of the Goldenville - Halifax Formation Transition Zone

	A1	A2	B1	C1	C2	D1	cD1	E1	cE1	E2	cE2
MAJOR ELEMENT ANALYSES											
SiO ₂	74.18	62.09	69.90	79.53	58.14	56.22	58.46	70.92	69.71	61.95	59.40
Al ₂ O ₃	13.01	19.35	15.54	10.95	21.85	17.81	17.90	13.68	12.63	22.74	23.04
Fe ₂ O ₃ *	4.96	7.52	6.40	2.84	9.49	9.84	8.94	5.95	6.91	5.40	6.32
MgO	1.38	2.40	1.93	0.94	2.92	2.04	2.35	2.23	1.67	2.47	1.76
CaO	0.42	0.45	0.72	0.60	0.27	1.77	1.09	0.06	1.16	0.07	0.09
Na ₂ O	3.01	2.44	2.76	2.75	2.05	0.66	0.93	1.06	0.93	1.60	1.27
K ₂ O	2.07	4.42	1.73	1.34	4.04	2.58	3.57	1.82	2.02	3.41	4.11
TiO ₂	0.62	0.92	0.66	0.46	0.84	1.03	0.88	0.75	0.69	1.24	1.20
MnO	0.06	0.09	0.21	0.18	0.25	4.72	2.92	0.21	0.31	0.25	0.26
P ₂ O ₅	0.10	0.24	0.11	0.11	0.10	0.16	0.11	0.03	0.06	0.11	0.06
S	0.01	0.01	0.01	0.02	0.01	0.15	0.55	3.17	1.92	0.04	1.30
CO ₂	0.15	0.06	0.01	0.26	0.03	2.95	2.09	0.00	1.46	0.03	0.04
C	0.02	0.01	0.02	0.01	0.01	0.07	0.18	0.12	0.53	0.69	1.15
total	100	100	100	100	100	100	100	100	100	100	100
TRACE AND RARE EARTH ELEMENT ANALYSES											
Ba	514	1193	338	239	835	1241	1081	499	601	871	1205
Rb	75	148	74	47	148	96	127	71	81	135	160
Sr	196	182	253	120	108	86	115	104	149	257	385
Y	22	35	34	21	25	37	33	30	23	34	46
Zr	211	227	226	208	185	171	154	168	214	162	186
Nb	12	18	16	10	18	16	13	13	11	19	16
Pb	14	14	22	16	16	80	28	25	11	20	12
Zn	62	101	90	37	121	98	114	134	89	85	96
Cu	16	26	16	5	15	53	45	45	34	3	23
Ga	17	27	18	12	27	24	24	20	17	28	27
Ni	21	45	33	10	46	49	54	25	23	12	24
V	83	142	97	45	139	194	144	96	83	183	174
Cr	70	119	97	45	116	116	112	67	71	138	160
Sc						23.1	16.8	11.0	11.1	22.0	24.6
Co							31		27		25
As	14.1	25.3	20.6	3.2	20.3	128.4	58.8	42.1	58.7		5.3
Sb	0.27	0.47	0.35	0.28	0.20	0.68	1.40	4.25	0.90	0.75	1.90
Ca						5.3	6.0	5.5	5.4	9.8	11.6
La	30	38	42	35	20	36	47	5	21	11	70
Ce						50	96	9	43	20	129
Sm						4.4	7.0	1.0	3.9	2.0	8.9
Hf	15.3	8.5	8.0	12.9	5.3	7.3	5.0	5.0	8.6	5.0	6.0
Ta							1.0	1.6	1.2	1.4	1.6
W						3.9	3.0	2.0	0.8	2.0	1.7
Au	1.9	1.0	1.6	1.6	5.7	7.9	3.6	3.5	1.9	1.5	2.9
Th	7.30	12.00	9.64	6.05	12.30	10.4	9.90	7.30	9.20	11.00	14.40
U	1.30	2.70	2.04	1.19	2.60	4.1	2.80	2.70	2.60	3.50	6.00
n	23	6	11	18	5	44	11	2	8	2	8

Legend for Table 1

A1	Goldenville Fm, New Hbr mbr, metawacke, Green Bay, Lunenburg County
A2	Goldenville Fm, New Hbr mbr, silty slate, Green Bay, Lunenburg County
B1	Goldenville Fm, Risers Beach mbr, metawacke, Crescent Beach, Lunenburg County
C1	Goldenville Fm, W Dublin mbr, metawacke, Bush Is, Lunenburg County
C2	Goldenville Fm, W Dublin mbr, slate, Bush Is, Lunenburg County
D1	Halifax Fm, Mosher Is mbr, argillite, Bells Cove, Lunenburg County
cD1	Halifax Fm, Mosher Is mbr, argillite, Caribou core LL81-5A, Halifax County
E1	Halifax Fm, Cunard mbr, metasiltstone, Bells Cove, Lunenburg County
cE1	Halifax Fm, Cunard mbr, metasiltstone, Caribou core LL81-5A, Halifax County
E2	Halifax Fm, Cunard mbr, slate, Bells Cove, Lunenburg County
cE2	Halifax Fm, Cunard mbr, slate, Caribou core LL81-5A, Halifax County

(Fm = Formation, mbr = member)

Major elements are reported in wt % and total Fe as Fe_2O_3 ; all analyses by standard atomic absorption analyses except P_2O_5 by colorimetric analyses; FeO, S, CO_2 and C determined by wet titration by Dalhousie University, Halifax, Nova Scotia. Trace elements are reported in ppm; all analyses done by X-ray fluorescence at Saint Marys University, Halifax, Nova Scotia. Trace metals are reported in ppm except gold (ppb); gold detection limit approximately 2 - 3 ppb. For comparison purposes, all mean gold calculations consider analyses below detection limit to be 1 ppb. All analyses done by instrumental neutron activation (INAA) by Bondar Clegg and Company, Limited, Ottawa, Ontario.

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LITHOLOGICAL CROSS-SECTIONS AND MINERALIZATION OF THE FARIBAULT BROOK AREA, JUMPING BROOK METAMORPHIC SUITE, WESTERN CAPE BRETON HIGHLANDS¹

P. Tallman², R. A. Jamieson² and A. L. Sangster³

Detailed logging of 2900 m of core from the Faribault Brook area, near Cheticamp, Cape Breton Island, has established a local lithological framework for mineralization. Previous work defined a regional stratigraphy for the Jumping Brook metamorphic suite, with schistose metabasite of tholeiitic composition at the base of the sequence, overlain by quartz-eye-bearing sericitic tuffs and metagreywackes, succeeded by interlayered pelites and semipelites (Jamieson *et al.*, 1987; Woods, 1986). Cross-sections through the metabasite-metasediment transition indicate a more complex relationship.

The deepest level reached by drilling is comprised of a 50 m thick sequence of interlayered metagreywacke, siliceous metagreywacke, metaquartzite, and quartz-sericite schist. Thin, interlayered metasediments and metabasites at the structural top of this sequence grade into a 75 m thick sequence of metabasite composed of weak to moderately foliated amphibolites and medium- to coarse-grained, equigranular metadiorites. Preserved contacts between interlayered metabasite and metasediment as well as between texturally distinct fine grained metabasites are parallel to the regional schistosity. Strongly foliated biotite-rich zones (<5cm to 1m

wide) which are common in metabasite, also parallel this schistosity.

A 40 m-thick zone composed of thinly interlayered metabasites, biotite-rich metabasites, quartzites, siliceous metagreywackes and metagreywackes overlies the metabasite. Metabasite in the upper 10 m of this zone is overlain by a buff, quartz-sericite schist or metagreywacke. Interlayered fine- to medium-grained, white and blue quartz eye-bearing, quartz-sericite schist, siliceous metagreywacke, metagreywacke, and chloritic metagreywacke, approximately 125 m thick, become increasingly chlorite-rich higher in the section. Open to tight folds, with axial planes parallel to the regional foliation, and brittle faults in hinge zones are common in these lithologies.

Pelites and semipelites grade upwards into chloritic metagreywackes which form the uppermost lithologic unit in the area. These metasediments are tightly to isoclinally folded and are commonly transposed parallel to the regional foliation.

A pink quartz-sericite schist cuts the regional foliation and apparent layering in highly schistose metabasite at the Marleau Showing in upper Grandin Brook. Siliceous competent margins, 10

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cm wide, suggest chilled margins. Similar possible intrusions are distinguished in drill core by colour, distinctive sulphide mineralization, and in one case by an apparent intrusive relationship with a dioritic metabasite. Field evidence suggests that this unit intrudes the basal siliceous metasediments and overlying metabasites; it does not appear above the uppermost metabasite layer.

The metabasites, metagreywackes, and metapelites were originally conformable units which have been structurally modified. Gross stratigraphy indicates two periods of sedimentation with intervening mafic volcanism. Anastomosing shear zones are common in the lower metasediments and metabasites whereas folding dominates in the upper metasediments.

Mineralization is ubiquitous and sulphide assemblages are highly variable. However, indications of pre-metamorphic sulphides are rare. Garnet overgrows sphalerite in quartz-sericite schist at the Galena Mine occurrence indicating a pre-metamorphic origin (Connors, 1986). The pink, possibly intrusive, quartz-sericite schist contains arsenopyrite + chalcopyrite + pyrite as cleavage-parallel disseminations which may also be pre-metamorphic.

There is a strong association between mineralization and shearing. The common assemblage of pyrrhotite + pyrite + arsenopyrite + chalcopyrite occurs in thin, foliation-parallel quartz veinlets hosted by biotite-rich, well foliated metabasites predominantly adjacent to siliceous metasediments. Disseminated, cleavage-parallel, anhedral pyrrhotite, pyrite and chalcopyrite, and subhedral to euhedral arsenopyrite are also associated with biotite-rich shear zones. The veinlets are isoclinally folded and transposed. The associated siliceous metasediments are weakly biotitic, streaky, recrystallized metaquartzites with rare

relict quartz eyes, and contain local disseminated chalcopyrite and pyrite. Arsenopyrite-rich seams, with trace pyrrhotite and pyrite, and minor quartz gangue and local garnet, are associated with high strain zones in metabasite at the Road 1a and Road 1b occurrences. Similar arsenopyrite-rich veins with traces of pyrrhotite and minor garnet are hosted by well foliated white-yellow quartz-sericite schist with disseminated arsenopyrite, minor sphalerite, chalcopyrite and galena at the Core Shack and Mountain Top occurrences. The relationship between the metabasite- and quartz-sericite schist-hosted mineralization is not clear, but the arsenopyrite mineralization may overprint the sphalerite + chalcopyrite + galena mineralization at the Core Shack and Mountain Top occurrences.

Folded and strongly boudinaged quartz veins commonly host some or all sulphides known in the area and may be associated with sulphide remobilization. Later, open folded, locally boudinaged to continuous quartz veins host minor sulphides or are barren. Late fracture-filling carbonate veins are common in the metasediments and locally host sphalerite + chalcopyrite + galena mineralization. Plagioclase-phyric diabase dykes, probably related to the Devono-Carboniferous Fisset Brook Formation, also host fracture-filling carbonate veins containing chalcopyrite + galena mineralization.

Pre-metamorphic sulphides are rare. Shear zones host remobilized polymetallic mineralization of undetermined origin. Arsenopyrite-rich veins may overprint some styles of mineralization. Remobilization of sulphides into veins is evident as late as the Devono-Carboniferous.

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LEAD ISOTOPE COMPOSITION OF GALENAS FROM METACARBONATE-HOSTED ZINC OCCURRENCES, CAPE BRETON, NOVA SCOTIA¹

A. L. Sangster² and R. I. Thorpe²

SUMMARY

Lead isotope analyses of galena, routinely obtained in support of ongoing metallogenic studies, are reported here for the metacarbonate-hosted zinc occurrences at Meat Cove, Lime Hill and Rear Boisdale. The isotopic compositions for Lime Hill and Meat Cove are similar to those for Grenville stratabound deposits and occurrences, whereas that for Rear Boisdale is significantly more radiogenic.

The Lime Hill and Meat Cove occurrences consist of widespread sphalerite mineralization, with minor associated pyrrhotite and pyrite, in serpentine-bearing marbles. In this regard they are chemically similar to many stratiform zinc occurrences (e.g. Balmat District, Salerno Lake, Northfield, Lynx, Leach and others) which are hosted by Grenville Supergroup rocks in New York, Ontario and Quebec. One isotopic analysis of galena from Lime Hill and triplicate analyses of one sample from Meat Cove have given ratios very similar to those reported for some Grenville Supergroup deposits (Table 1).

An interpreted Grenville affiliation for the Meat Cove occurrence is in accord with recently published zircon U-Pb data for the Lowland Cove syenite which indicate a metamorphic age of 1040 ± 40 Ma and an

intrusion age of 1100 - 1500 Ma (Barr *et al.*, 1987). The syenite hosts the deposit within a large marble xenolith.

A similar lead isotope composition for the Lime Hill zinc deposit, in conjunction with similar ore composition (i.e. low Pb, Ag) and host marble chemistry (i.e. high MgO, SiO₂), suggest that the occurrence may also be classified with Grenville Supergroup zinc occurrences. This contention is not supported by recent work by Raeside (1987), who characterized the paragneiss containing the Lime Hill marble as a product of low pressure metamorphism and unlike the medium to high pressure metamorphism of Grenville Supergroup sediments. Raeside correlated the Lime Hill gneiss with the Kellys Mountain gneiss which was determined to have a metamorphic Rb/Sr age of 701 ± 66 Ma (Olszewski *et al.*, 1981). The depositional age of the gneiss is not known.

The significance of the Grenville signature from Lime Hill galena is open to substantial interpretation. Two possibilities are as follows:

1. the Kellys Mountain gneiss is a correlative of Grenville Supergroup metasedimentary rocks; it escaped moderate to high grade Grenville metamorphism only to be involved in a non-Grenville metamorphic event at 701 ± 66 Ma.

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Table 1. Comparison of lead isotope ratios from the Lime Hill and Meat Cove deposits with representative values from Grenville Supergroup-hosted stratabound sulphide deposits.²

Location	206Pb/ 204Pb	207Pb/ 204Pb	208Pb/ 204Pb
Meat Cove ¹	17.209	15.513	36.636
rerun	17.026	15.480	36.438
rerun	17.166	15.512	36.620
Lime Hill ¹	17.000	15.562	36.718
Balmat - # 2 ²	16.934	15.506	36.440
Balmat-Loomis B ²	16.770	15.442	36.330
Sheffield Twp. ³	16.751	15.344	36.240
Northfield ³	16.920	15.421	36.280
Lynx (Long Lake) ¹	16.763	15.365	36.239
New Calumet*, ³	16.438	15.327	36.020
Tetreaault*, ³	16.311	15.377	35.880
Rear Boisdale ¹	18.530	15.678	38.263

2. the Lime Hill zinc occurrence is post-Grenville in age and was hydrothermally deposited in the Lime Hill gneissic complex, prior to regional metamorphism; from a solution which derived its lead content exclusively from a Grenville basement; this would require a granulite facies Grenville source.

The authors prefer the first option but more work is required to define the depositional age of the Lime Hill gneissic complex.

At Rear Boisdale in the Boisdale Hills, George River marble, which has been historically correlated with the Lime Hill and Meat Cove marbles, contains a poorly exposed but somewhat

¹ previously unpublished

² from Fletcher, 1979

³ from Fletcher and Farquhar, 1982

* volcanic-hosted, stratiform, base metal deposits

similar Zn-Pb-Ag occurrence. However, galena from Rear Boisdale has a significantly more radiogenic isotopic composition (Table 1), indicating a different metal source and possibly different mode of origin. The Rear Boisdale galena is isotopically similar to galenas from occurrences related to Devonian intrusions.

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AEROMAGNETIC TOTAL FIELD, GRADIOMETER, VLF SURVEYS - NOVA SCOTIA¹

E. Ready² and D. Teskey²

The location for the 1985-86 survey released in 1987, and the 1986-87 survey to be released in 1988 are shown in Figures 1 and 2, respectively. In both cases flight line separation was 300 m at 150 m above ground. VLF-EM data have also been recorded. The vertical gradient and total field data are presented as 1:25 000 contour maps and as 1:50 000 colour interval maps. The VLF quadrature data are plotted as stacked profiles on the back of the

vertical gradient colour maps so that they may be viewed concurrently with the gradiometer data using a light table. The zero contour of the vertical gradient very closely outlines the contacts between rock masses with contrasting magnetization such as volcanic and sedimentary units, whereas the VLF data are useful for the delineation of near surface conductors and zones of contrasting conductivity.

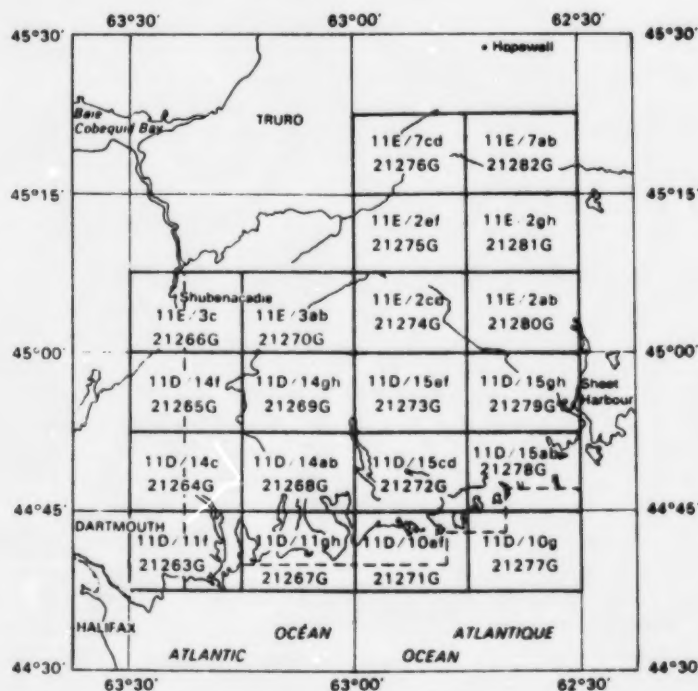


Figure 1. Index map of the Nova Scotia Aeromagnetic Survey, 1985-86

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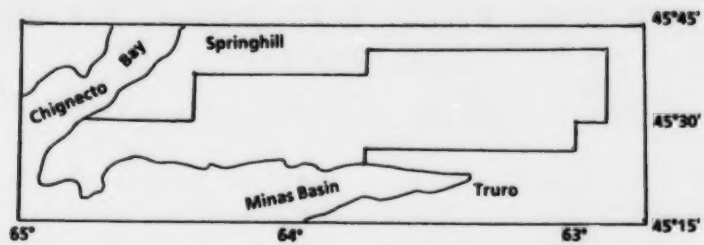


Figure 2. Location map of the Nova Scotia Aeromagnetic, Gradiometer Survey, 1986-87

DOWNHOLE GEOPHYSICS AT THE YAVA LEAD DEPOSIT, 1987 FIELD SEASON¹

C. J. Mwenifumbo², P. G. Killeen² and A. Cinq-Mars²

INTRODUCTION

Seven vertical holes were drilled at the Yava lead deposit during the 1987 field season. These holes were drilled to investigate the zinc mineralization observed in the northwestern part of the West Extension Zone during the 1986 summer drilling (J. M. Patterson, personal communication, 1986). According to Patterson, the enrichment of zinc indicates the possible existence, downdip from the West Extension Zone, of a zinc deposit similar to the Laisvall lead-zinc mine in Sweden. Downhole geophysical measurements were carried out to determine the geophysical characteristics of the deposit to aid in future exploration and evaluation of this or other similar deposits. The holes with enhanced Zn values were of particular interest for determining the changes in the geophysical responses when moving from the low to high zinc mineralization.

Three of the seven holes drilled (i.e. 418, 420, 421) were geophysically logged with natural gamma ray, spectral gamma gamma (density and spectral ratio), induced polarization (IP), resistivity, self potential (SP), magnetic susceptibility (MS), temperature and temperature gradient. Interpretation of the 1986 logging results had indicated that IP is the optimum technique for surface exploration of the Yava type lead deposit. However planned surface IP

work for 1987 field season was cancelled due to equipment problems.

The three holes that were logged ranged 44-57 m in depth and the lithology penetrated was sandstone with occasional black shales and limestone pebble conglomerate underlain by the Windsor Shale. The basement rocks consist of rhyolite overlain by brecciated rhyolite. Sulphide mineralization consists of disseminated pyrite, galena and sphalerite. In holes with significant Zn values, the mineralization seems to be zoned. Sphalerite dominates the upper parts of the sandstone while galena is more prevalent in the lower parts. The highest Zn values were observed in hole 420 (a 1 m thick zone of 2.2% Zn).

DOWNHOLE GEOPHYSICS

The major lithologic units of sandstone and the Windsor Shale are well delineated by the natural gamma ray, resistivity and, in a number of cases, SP logs. The sandstone has fairly low radioactivity, high resistivity and low self potentials whereas the Windsor Shale is characterized by relatively higher radioactivity, lower resistivities and more negative self potentials. Lower resistivities within the sandstone indicate the presence of black shales or pyrite/galena mineralization. The black shales within the sandstone are

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YAVA LEAD DEPOSIT, NOVA SCOTIA

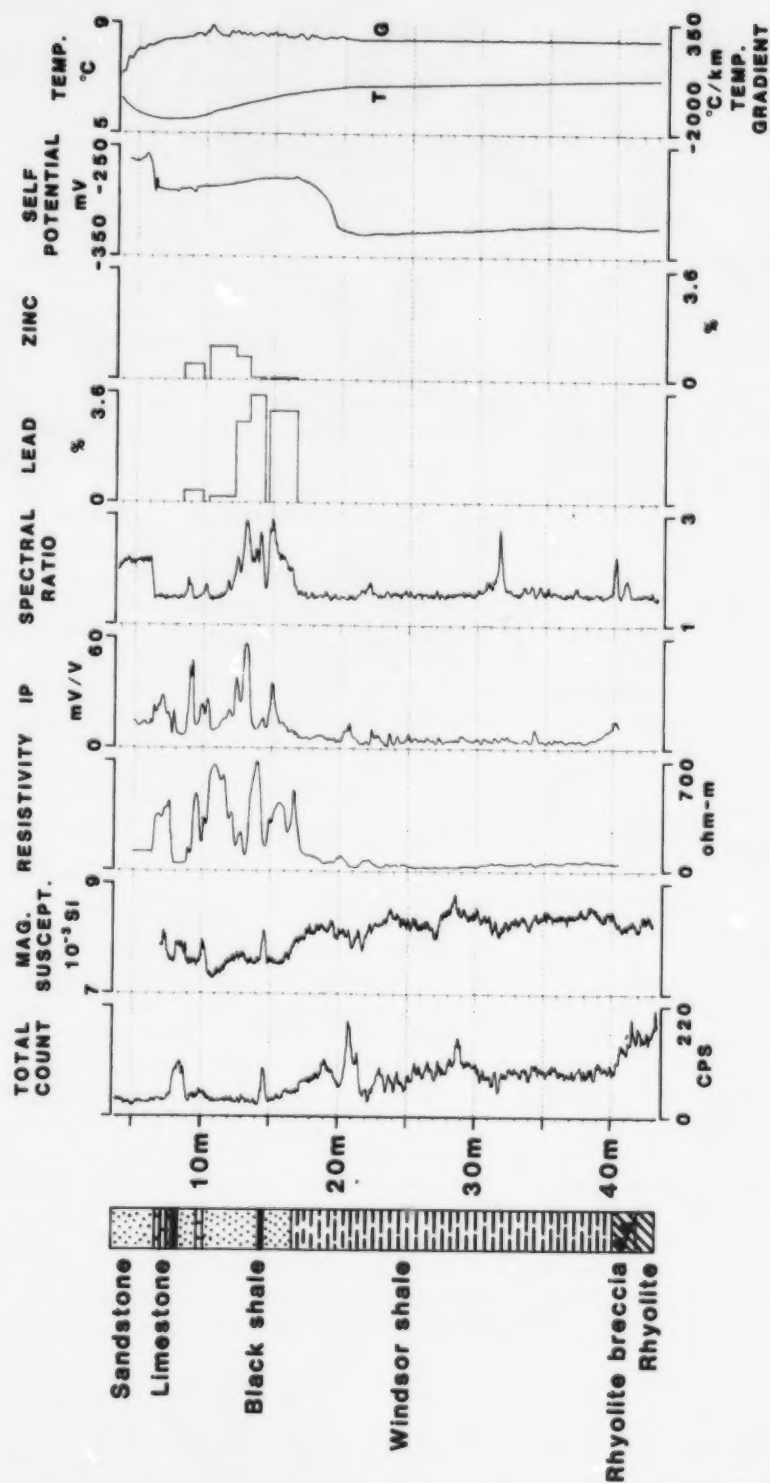


Figure 1. Borehole geophysical logs from hole 421 at the Yava deposit. Recorded with the Geological Survey of Canada R&D logging system, the logs shown here include total count (natural gamma), magnetic susceptibility (MS), resistivity, induced polarization (IP), spectral ratio (related to heavy element content), self potential (SP), temperature (T) and temperature gradient (G)

also characterized by higher levels of radioactivity.

Figure 1 shows a suite of geophysical logs, lithology, lead and zinc content along the length of hole 421. The observed responses are typical of the rock units and mineralization of this deposit. The mineralization is delineated best by IP and the gamma-gamma spectral ratio. High IP and high spectral ratios indicate the presence of mineralization (galena and/or pyrite). High IP effects do not necessarily indicate high lead mineralization because the pyrite responds in the same way as galena. Sphalerite does not respond to electrical techniques, however because of its close association with pyrite at this deposit, high Zn values correlate with high polarizability. The gamma gamma spectral ratio is directly correlated with the lead concentration and offers potential as a direct method of *in situ* assaying for Pb. Detailed sampling of the mineralized zones of 2 holes has been carried out and the samples are being assayed for Pb, Zn and Fe to determine the relationship between these heavy elements and the spectral ratio.

Figure 2 shows a section of 5 holes through the West Extension Zone illustrating the correlation between

the spectral ratio and the lead content. The spectral ratio indicates lead mineralization at the Windsor Shale/rhyolite breccia contact and this has been verified during a closer examination of the drill core. High spectral ratios within the Windsor shale may not always be due to lead mineralization. Barite (atomic number, Z=56) occurrences within the shales will give high spectral ratios. However, anomalies due to barite can be easily distinguished from those due to lead mineralization by examining the IP response. There is no IP effect within baritic zones if they are devoid of sulphide mineralization (see Fig. 1, anomaly at 32.5 m). The concentrations of sphalerite (<2% zinc) and pyrite are too low to cause a response on the spectral ratio log (atomic number, Z=26, 30 for Fe and Zn, respectively, compared to Z=82 for Pb). There is no measurable change in the geophysical characteristics of the host rock from zones low in zinc to those enriched in zinc.

Thirteen holes were geophysically logged at the Yava West Extension Zone including those carried out during the 1986 field season. Most of these data are being analyzed and interpreted as part of an M.Sc. thesis (A. Cinq-Mars) at Ecole Polytechnique, Montreal, for completion in 1988.

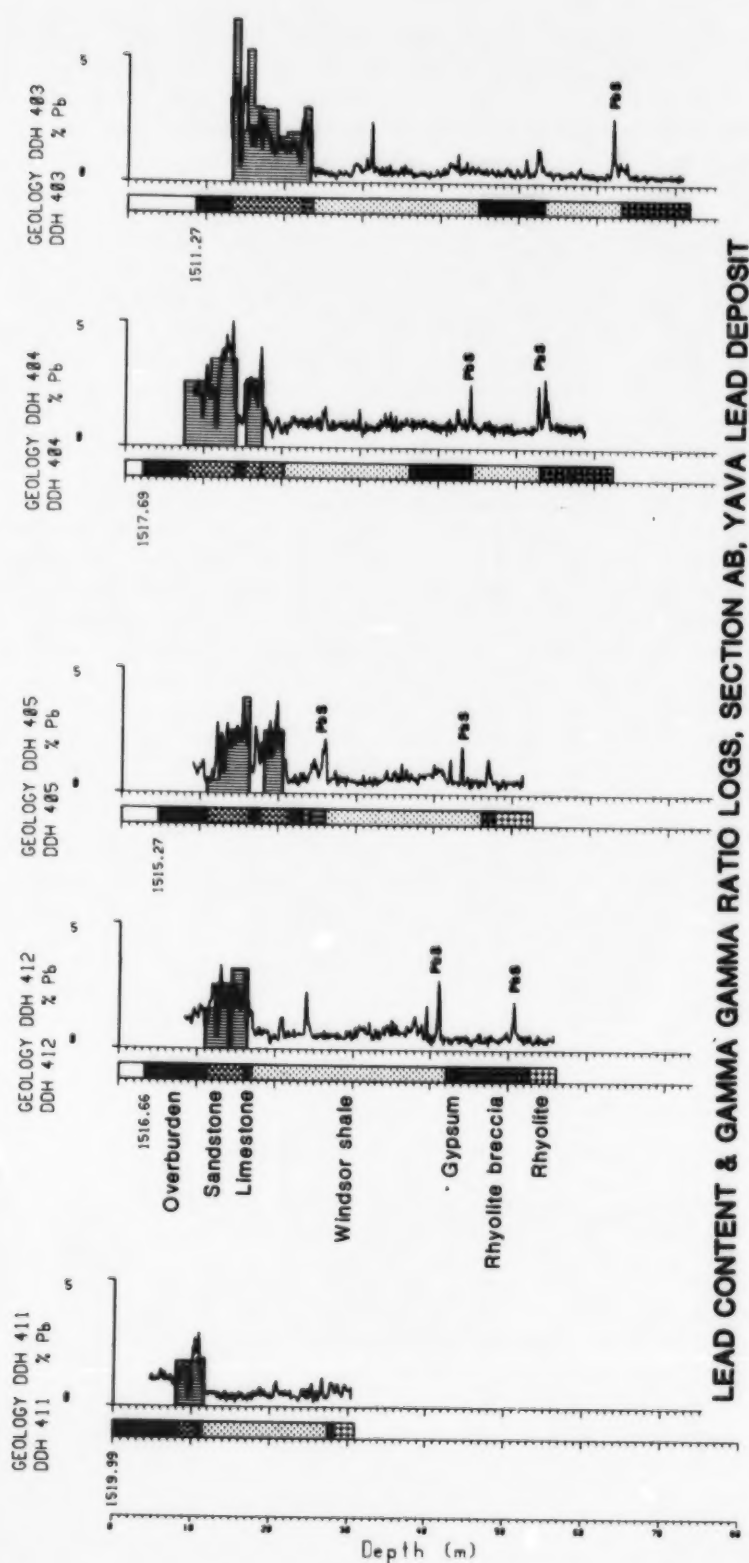


Figure 2. Spectral ratio logs from 5 holes in a section crossing the West Extension Zone at the Yava deposit, showing the relationship with lead content indicated or cross-hatched

SEISMIC SURVEYS: CUMBERLAND BASIN AND OFFSHORE CAPE BRETON ISLAND, NOVA SCOTIA¹

D. S. Bromley²

Since 1985, the Geological Survey of Canada (GSC) has been conducting high resolution seismic surveys under the Canada - Nova Scotia Mineral Development Agreement. In these studies over 230 line-km of data was collected within onshore and offshore areas of Nova Scotia. The main objective of this project was to attempt to delineate regional structure of Carboniferous strata in the Cumberland Basin and offshore areas of western Cape Breton Island (Bromley and Hunter, 1986). Detailed mapping of coal-bearing structures within the Upper Carboniferous groups near Springhill was also of interest.

During June-July 1985, an 8 km test line was run into the Cumberland Basin west of Springhill. Several different seismic sources and geophone arrays were tested on this line to find the optimum geophysical parameters for the area. In order to achieve maximum depth of penetration while still maintaining the desired high resolution frequencies, it was determined that the best source and array choice was a small explosive source (less than 0.5 kg) along with an array of 3-9 geophones per group.

These initial studies led to the planning of a large-scale seismic survey. During November-December 1986, a further 50 line-km of data were collected under contract by Geophysics G.P.R. of Longueuil, Quebec. This study

was successful in outlining many Carboniferous reflectors within the Cumberland Basin. Figure 1 is a portion of processed line SL-1002, showing a north-south profile of part of the basin.

The post-survey data processing for all onland work was done by Rileys Seismic Processors of Calgary. Upon completion of computer processing of all 1985-86 data, a final survey was planned for 1987. The aim of this work was to ensure complete coverage over the Cumberland Basin and also to enhance some of the critical areas identified in previous surveys. Approximately 30 line-km of data were gathered between June-August 1987 by GSC personnel. These data are currently in the final stages of computer processing in Calgary. Once processing is completed, all results will be published as an open file report and a GSC paper will be forthcoming.

During September 1985, 2 marine geophysical studies were done off the west coast of Cape Breton Island. Geomarine Associates Limited of Halifax received the contract. The first survey covered the offshore areas around Port Hood and Henry Islands. Four seismic lines totalling 25 line-km were run in an attempt to map the subsurface structure on the "six foot" coal seam. The results of the survey state that the "six foot" seam is

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expected to occur at a depth of 1100 ± 110 m below sea level near the centre of Henry Island (LaPierre, 1986a).

The second marine seismic survey was completed offshore of Inverness. More than 85 line-km of data were gathered in a 5 km x 16 km grid pattern. The main objective of this survey was to provide control for projecting the depths of the "seven foot" and "thirteen foot" coal seams offshore. One of the constraining factors of this survey was the lack of seismic coverage across the nearshore Inverness Fault which is overlain by very shallow water (5-15 m). However a structure contour map of the "seven and thirteen foot" seams was produced after a 52 m vertical displacement of strata was calculated across the Inverness Fault (LaPierre, 1986b).

The results of these studies and other marine geophysical work in the area are being presently compiled as part of a Nova Scotia Department of Mines and Energy publication.

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INVESTIGATIONS OF COAL FROM THE PICTOU COALFIELD, NOVA SCOTIA¹

G. M. Yeo², W. D. Kalkreuth³, M. Tomica³, G. Dolby⁴ and J. C. White⁵

INTRODUCTION

The Pictou coalfield lies in north central Nova Scotia. Although current production is very small, estimated reserves are considerable and recent deep drilling suggests more potential. These coals are attractive for both the thermoelectric power generation and some metallurgical applications because of the relatively low sulphur content and high rank.

The coal is hosted by the Stellarton Group and restricted to a small synsedimentary basin designated the Stellarton Graben; this is coeval with the lower Pictou Group north of the graben. Four orders of rhythmic sedimentation can be recognized in the Stellarton Group namely (1) member pairs, (2) beds, (3) lithotypes/mesobands, and (4) microlithotypes/laminations. The studies outlined in this paper were done at the bed and lithotype scale.

Studies of petrographic (G. Yeo, M. Tomica, W. Kalkreuth), palynologic (G. Dolby), and geochemical (D. Birk, J. White) variation of selected coals were undertaken as part of the Stellarton Basin Analysis Project, to learn more about paleoenvironmental controls on coal quality in the Pictou Coalfield, to refine late Carboniferous

chronostratigraphy locally, and to assess the potential of the coals as a source for rare metals.

The Acadia, Foord and MacKay seams were chosen as respective representatives of the lower, middle, and upper coal-bearing members of the Stellarton Group. The Munro seam, a shaly coal near the base of the lower Pictou Group, was also investigated to compare a coal seam from a predominantly fluvial setting with the lake margin/deltaic Stellarton coals, and to test the hypothesis that the Munro seam might be correlative with one of the Stellarton coals.

COAL PETROLOGY

Vitrinite is the dominant maceral group in all sampled seams, suggesting that the original peat accumulated under predominantly wet forest swamp conditions. Diessel (1986) showed how ratios of specific maceral combinations, used as indicators of the proportions of plant materials, and depositional and diagenetic conditions, define particular peat-forming environments (e.g. limnic, fen, forest swamp, etc.). This scheme was applied to the Pictou coals to document changes during peat accumulation. (The maceral terminology of Bustin *et al.* (1985) is followed below).

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In the Acadia seam, the predominant vitrinite macerals vary laterally. Inertinite varies inversely with vitrinite. Inertinite macerals show some positive correspondence with shale abundance. Liptinite is a minor component except in the lower part of the seam. Sporinite is the dominant liptinite maceral, but alginite and liptodetrinite are high in the lower part of the seam. Coal facies variation suggests that alternating limnic and swampy conditions in the lower part of the seam gave way to mixed fen and forest swamp conditions (i.e. increased drying and tree density). Peat accumulation was interrupted by a major flood, represented by a shaly band. Wet forest swamp conditions were resumed. These gave way to fen, and finally limnic conditions (i.e. increased wetting and reduced tree density).

In the Foord seam, as in the Acadia seam, inertinite varies inversely with vitrinite, and liptinite is a minor maceral group. In two boreholes drilled in the central part of the basin, vitrinite B (matrix vitrinite) is the dominant vitrinite form, fusinite and inertodetrinite are the main inertinites, and sporinite and cutinite are the chief liptinite macerals. In contrast, in a borehole drilled toward the southern edge of the basin, vitrinite A (clean banded vitrinite) is the predominant vitrinite form, fusinite and inertodetrinite are the chief inertinite macerals, and liptodetrinite is the main liptinite maceral. The Foord seam in this borehole is a shaly coal. Vertical coal facies variation suggested alternating limnic and wet forest swamp conditions (i.e. flooding and drying). Six episodes of peat accumulation can be recognized. Drier conditions towards the basin edge are suggested by lower liptinite content.

In the lower MacKay seam, the dominant form of vitrinite is variable.

Vitrinite B is the main form on the limbs of the McLellan Syncline. Vitrinite A is more abundant toward the syncline axis. Liptinite displaces inertinite as the second most abundant maceral group toward the limbs of the McLellan Syncline. The main inertinite macerals are fusinite and inertodetrinite. The chief liptinite maceral is sporinite. Mineral matter is highest to the northwest. Coal facies variation suggests alternate drying and flooding under forest swamp, marsh and lake margin conditions.

In the upper MacKay seam, vitrinite A is the dominant maceral. The liptinite maceral group (mainly sporinite and cutinite) is less abundant than the inertinite group (mainly fusinite and inertodetrinite). Mineral matter is most abundant to the northeast. Coal facies analysis suggests that the upper MacKay Seam was deposited under conditions ranging from marsh (in the west) to forest swamp (in the east).

In the Munro seam, subordinate inertinite and liptinite co-vary inversely with vitrinite. Sporinite and cutinite and the minor liptinite macerals co-vary inversely with mineral matter. Alginite is relatively high. Mineral matter content is high compared to the Stellarton coals. Coal facies variation suggests that virtually continuous flooding conditions must have prevailed with alternating wet forest swamp and limnic conditions. The upper part of the seam is highly variable. The Munro seam cannot be correlated petrographically with any of the Stellarton coals examined.

Coalification gradients for coals from the Stellarton Group are much higher than one based on coals and shales in a deep borehole in age-equivalent lower Pictou Group strata north of Stellarton Graben. Since there is no evidence that the Stellarton Group was more deeply buried than nearby lower Pictou strata, the

higher rank of the Stellarton coals is most likely due to anomalous heating within the graben. This might be caused by deeply circulating groundwater of frictional heating in the fault zones.

PALYNOLOGY

A provisional "index species" range chart for the late Westphalian of the Pictou Coalfield was developed by G. Dolby. Tentatively, four zones are recognized. Zones I and III are approximately equivalent to Zones IX and X of Smith and Butterworth (1967), while Zone II is transitional. Zones I to III are correlative with Zone A, the *Vestispora* Zone of Barss and Hacquebard (1967). Zone IV corresponds to Zone B or *Torispora* Zone of Barss and Hacquebard (1967). Zones I to III are assigned to the Westphalian C, while Zone IV is Westphalian D. This age assignment, based on species ranges from western Europe and central North America, is slightly younger than that of Barss and Hacquebard (1967), which was based on the macrofloral zonation of Bell (1938).

Smith (1962) recognized 4 miospore association in the lower Westphalian of Yorkshire, which he correlated with coal lithotypes and environments of deposition. The 4 associations are:

1. the Incursion Phase, developed during flooding;
2. the Densospore Phase, developed during dry conditions (peat raised above the water table);
3. the Lycospore Phase, developed in very wet conditions, and;
4. the Transition Phase, intermediate between Densospore and Lycospore phases.

All but the Densospore Phase can be recognized in samples from the Pictou coalfield.

The Acadia seam is assigned to Zone I, and is therefore upper early Westphalian C. The Lycospore Phase is restricted to the bottom and top of the

seam. Transition and Incursion phases alternate through the central part of the seam.

The Foord seam, assigned to Zone II, is the lower late Westphalian C age. As noted by earlier workers, *Torispora* is common in this seam. Lycospore, Transition and Incursion phases alternate throughout the sequence.

The upper and lower MacKay seams are assigned to Zone IV and therefore are early Westphalian D. In Upper MacKay coals the Lycospore Phase predominates with some Incursion Phase influence. The lower MacKay seam shows more variability as Incursion, Lycospore, and Transition phases were recognized.

The Munro seam, assigned to Zone II, is of middle Westphalian C age. In contrast to the Foord seam, which is about the same age, *Torispora* is uncommon. However, it is abundant in a thin coal (Seam 3) above the Munro seam. Incursion or Transition Phases alternate with the Lycospore Phase.

COAL GEOCHEMISTRY

Neutron activation analyses of coal ash shows concentrations of some metals (i.e. Zn, As, Cd, Ga and Gc) to be well above their Clarke values. Concentrations of Zn, As, Cd and Ga are generally higher in the fluvial, lower Pictou Group coals than in the limnic, Stellarton coals. In general, metal contents are lower than those reported for Sydney Basin coals. The element Ge, which is typically concentrated in limnic coals, was not analysed.

SUMMARY

Earlier coal studies (e.g. Hacquebard and Donaldson, 1967) showed that Stellarton coals were deposited under very wet, lake margin conditions. The coal maceral study outlined here compliments this work and documents

shifts between subenvironments within the lake margin setting as water levels and plant assemblages changed. The coal facies variation scheme of Diessel (1986) developed for Permian coals in eastern Australia, appears to be applicable to Carboniferous coals in eastern Canada, although allowances must be made for differences in coal facies ranges due mainly to different flora.

The new palynological data also refines earlier work. The Stellarton Group records nearly continuous deposition from early Westphalian C to early Westphalian D time. Deposition of the lower Pictou Group began before late Westphalian C. The Stellarton Group also reflects the last episode of late Paleozoic faulting in the northern Appalachians. This places an upper age constraint on the timing of the Hercynian Orogeny in this region. Environmental shifts indicated by miospore assemblages corroborate those suggested by petrographic data.

Many metals of growing importance to advanced industrial technology are concentrated in coals. Coal ash could become a major source for Ge and Ga. Both metals are locally concentrated in the Sydney coals, however, Ga is relatively low and no Ge data exists as yet for the Pictou coals.

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SEDIMENTOLOGY, TECTONIC CONTROL AND RESOURCE POTENTIAL OF THE LATE DEVONIAN-EARLY CARBONIFEROUS HORTON GROUP, CAPE BRETON ISLAND¹

A. P. Hamblin²

INTRODUCTION AND OBJECTIVES

Post-Acadian basal clastics beneath the Windsor Group were deposited in fault-bound extensional basins in western Cape Breton Island. The petroleum and mineral potential of these nonmarine sediments have long been recognized but these aspects have not been investigated using sedimentological data as a predictive tool. Although in the initial stages, this approach may help establish the complex relationships between (1) tectonic setting, (2) syndepositional structural movements, (3) facies deposited, (4) facies geometrics and organization, and (5) resource potential of the sequence.

In the Lake Ainslie, Wycocomagh and Baddeck areas of western Cape Breton Island, 11 500 m of strata were measured in 17 sections (Fig. 1). Due to wide outcrop separation, variable outcrop quality, great lithological variation and post-depositional structural complications, correlation and interpretation are as yet tenuous. Thirty palynological samples will aid in time correlation of the probably diachronous facies. The next field season will extend observations to the north and will include examination of available subsurface material.

PREVIOUS WORK

The Horton depositional basins have been viewed as (1) a broad downwarp (Bell, 1958; Kelley, 1967) or active fault-bound graben (Belt, 1968) with internal fault-bound uplands separating sub-basins, or as (2) small active pull-aparts within a major dextral strike-slip fault zone (Bradley, 1982). In any of these cases, individual sub-basins would have a distinct local stratigraphy and structural history, although the regional patterns of development might be very similar.

Norman (1935), Bell (1958), Murray (1960) and Kelley (1967) identified a general stratigraphic sequence for these ?Frasnian-Tournaisian clastics. This includes:

1. Fisset Brook ("pre-Horton") basic volcanics, interbedded with red sediments up to 500 m thick, of a local distribution,
2. Craguish ("lower Horton") red and grey coarse clastics, up to 1500 m thick, thickest near the basin margin,
3. Strathlorne ("middle Horton") grey fine clastics and limestone, up to 300 m thick, thickest near basin centre,
4. Ainslie ("upper Horton") grey and red clastics, up to 700 m thick,

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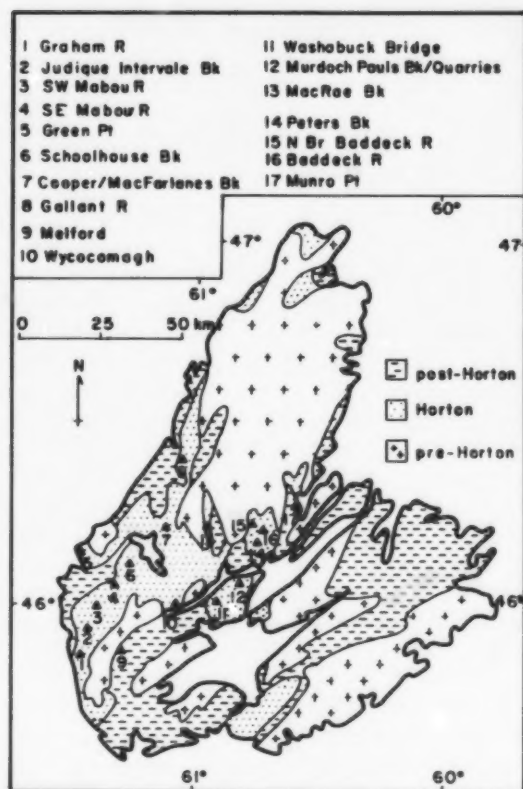


Figure 1. Generalized geological map and measured sections

sharply overlain by Macumber limestone (basal Windsor).

SUMMARY OF OBSERVATIONS

The tripartite stratigraphic scheme of the literature can be recognized on a gross scale in most sections. These lithologically-defined units are probably diachronous megafacies which represent tectonically (or climatically?) - controlled depositional settings arranged laterally in the fault-bound basins. All the megafacies may not be well developed at each section, depending on the position within the basin (Fig. 2), and may not correlate precisely, in time, between sections.

Fisset Brook volcanics were

observed only at Cooper Brook (about 300 m exposed), consisting of pink fine crystalline rhyolite (lower), green fine crystalline basalt with a few thin flow breccias (middle), and reddish brown fine crystalline highly altered vesicular basalt (upper). Blanchard *et al.* (1984) dated these rocks at 370 ± 20 Ma and interpreted them as continental tholeiitic basalts extruded near the margins of extensional basins.

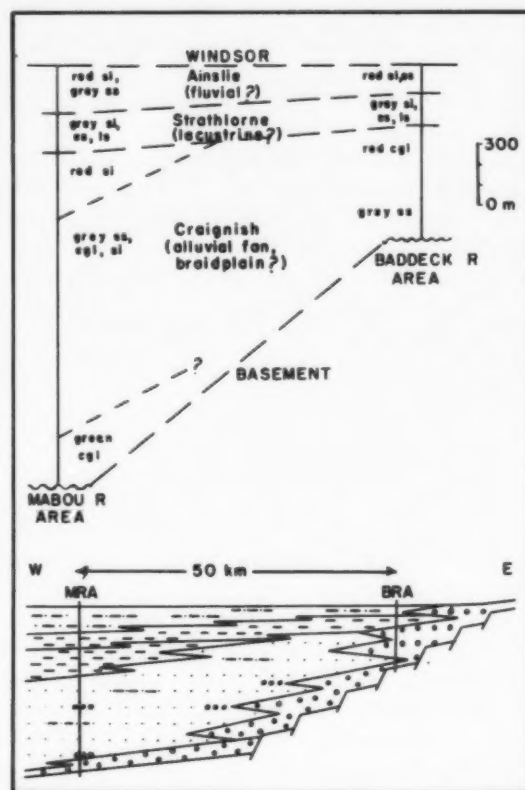


Figure 2. Horton depositional setting and megafacies

The Craignish megafacies, exposed in a more basal position on Graham River, consists of:

1. lower, green and grey, quartzitic conglomerate with some fine sandstone and siltstone, and many diorite sills;
2. middle, thinly bedded, grey, fine to coarse, sandstone with minor conglomerate and siltstone;

3. upper, thinly bedded, red siltstone and grey, fine to coarse, sandstone in a 1 700 m sequence with an overall fining upward trend.

These units can be interpreted as the deposits of alluvial fans and braid plains in an overall waning tectonic cycle. On Baddeck River, in a more marginal position, the Craignish consists of thinly bedded red polymictic, matrix-supported conglomerate and pebbly sandstone with 700 m thick red siltstone units. Here the Craignish can be interpreted as the deposits of alluvial fans near basin margins.

The Strathlorne megafacies, well exposed in Baddeck and Washabuck areas, consists of 150-200 m of dark grey siltstone to mudstone with very thinly interbedded, rippled, very fine sandstone and limestone commonly burrowed and organic-rich. Stacked 2-20 m coarsening (and shallowing) upward sequences are common. There is a thin but distinct coarsening upward shoreline sequence between Craignish and Strathlorne megafacies. This suite of sediments can be interpreted best to represent shallow lacustrine deposition, perhaps during a period of relative tectonic quiescence. In the Mabou River area, the Strathlorne megafacies consists of 200-400 m of similar sediments but with thick intervals of green or grey, calcareous, very fine to fine, sandstone with ripples and crossbeds which together may represent an area of greater sediment input and slightly higher energy within the lacustrine basin.

The Ainslie megafacies also occurs in two distinct forms depending on basin position but both represent tectonic rejuvenation and infilling by continental sediments. Near basement blocks where the Horton is thinner (e.g. Whycocomagh, Green Point, Washabuck), the megafacies commonly consists of 100-500 m coarsening upward sequences of polymictic pebbly

coarse sandstone to matrix-supported conglomerate, interpreted as alluvial fan sediments. Away from active fault margins (e.g. Mabou River, Baddeck River) the megafacies consists of 100-400 of micaceous interbedded red siltstone and green or grey calcareous fining upward fine sandstone units, with some irregular green limestones, interpreted as fluvial/floodplain deposits. The uppermost Horton is always sharply but conformably overlain by distinctive dark laminated limestone of the Macumber Formation (Basal Windsor).

RESOURCE POTENTIAL

The lower and upper Horton clastics have some porosity and permeability and could provide good aquifers for mineralizing fluids and(or) reservoirs for hydrocarbons. The Strathlorne megafacies and the Windsor carbonate/evaporite sequences could act as source rocks (for metallic ions or hydrocarbons) and as traps (redox interface of seal rock). Thus the overall tectonic, stratigraphic and depositional settings are suitable for creating metallic deposits (Cu, Pb, Zn, Au and U) and petroleum accumulations. The setting is reminiscent of the classic Kupferschiefer copper deposits of Europe (Kirkham, 1978) and the upper few metres of Horton are typically green-stained in most sections. Oil seeps are well known in the area and exploratory drilling has proceeded sporadically since 1869 with limited success (McMahon *et al.*, 1986), although the Stoney Creek oil and gas field produces from partly correlative units. Numerous structural features may also enhance resource potential.

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COMPUTERIZATION OF COAL EXPLORATION DATA FOR NOVA SCOTIA¹

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SUMMARY

This project, dedicated to construction of comprehensive computer files of coal geological and coal quality information for the coalfields of Nova Scotia, entered its third year in 1987 under the Canada - Nova Scotia Mineral Development Agreement. The reader is referred to Hughes, MacNeil and Watson (1986) for an outline of the rationale, procedures and objectives of the project.

Compilation, interpretation, coding and verification of location, lithological and coal quality data from boreholes and some mine workings in the Sydney and other smaller coalfields of Cape Breton Island was completed in the first phase of the project (Hughes, MacNeil and Watson, 1987).

The second phase of the project has involved preparing similar computer files for coalfields of the Cumberland Basin and Debert-Kemptown. Available data comprised 395 boreholes totalling 48 500 m, about 70 outcrop descriptions and 1250 coal sample analyses. This work proceeded through 1986-87.

Preliminary work utilizing the Sydney coalfield database was done this year at the Institute of Sedimentary and Petroleum Geology in Calgary, Alberta. To test the success of integrating the several topographic co-

ordinate systems which have been used, simple posting maps are generated to show borehole locations and topography in relation to the national 6⁰ UTM co-ordinate base.

During 1987-88, computer files will be prepared for similar data from the Pictou coalfield.

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PRELIMINARY RESULTS FROM A SPATIAL DATA INTEGRATION PROJECT IN EASTERN NOVA SCOTIA USING A MICRO-BASED GEOGRAPHIC INFORMATION SYSTEM¹

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A large multi-layer spatial dataset has been compiled for an area, approximately 100 km x 100 km, east of 62°30'W but excluding Cape Breton. The layers which are stored as digital images, include bedrock geology (compiled recently at 1:150 000 scale), surficial geology, stream and lake sediment geochemistry using catchment basins, topographic relief, airborne gamma ray and magnetic data, mineral occurrences, geological structure, and satellite imagery. The general goal of the project is to use digital image analysis and geographic information systems analysis to facilitate comparison of different data types, and aid the geologist in making syntheses which require diverse types of regional survey data.

Two parallel micro-computer-based systems are employed. One system uses software designed to enhance and display images, particularly satellite and airborne data; the other uses geographic information system software for analyzing and modelling relationships between data layers. Some preliminary results are displayed at the poster session and in a computer demonstration at the 1987 Nova Scotia Department of Mines and Energy Open House.

Lineaments derived from satellite

imagery, augmented by digital elevation and magnetic data, were statistically analyzed for a spatial association with known gold occurrences. Lineaments oriented northwest show a significant association with gold (Bonham-Carter *et al.*, 1985).

Lake sediment data from the Meguma terrane is displayed using catchment basins associated with sample sites. Using regression analysis techniques the relationship between geochemical response and surface and bedrock map units is shown to be weak, particularly in contrast to the strong relationship between bedrock geology and geochemical response in the Cobequid Highlands (Bonham-Carter *et al.*, 1987). Three multi-element associations (derived using principal components analysis) are persistent throughout the area. The most important is an association of Zr, Ti, Rb, Th, Li, Nb and F. A somewhat similar association in the Liscomb area lakes was interpreted by P. S. Giles (personal communication, 1987) as possibly due to heavy mineral fractionation. The spatial distribution of this component is coherent, but shows no clear relation to the mapped geology. The second association is Pb-Zn-Cu and As, showing northwest linear trends in the western part of the area of possible metallogenic significance. The third

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association is Au-W which again has a distinct spatial distribution, but is not readily explained by the geological map.

Several other aspects of these data are under current or planned investigation, some of which include radiometric response of mapped units in the Antigonish Highlands, prediction and removal of geological background from Antigonish stream sediment geochemistry to produce anomaly maps, and modelling of gold and base metal occurrences.

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